THE IDENTIFICATION OF MOLECULAR SPECTRA

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By

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PREFACE

THESE tables have been constructed with the aim of facilitating the identification of molecular spectra. Several excellent books have been written dealing with the theory of molecular spectra and some have included collections of molecular constants derived from the analysis of such spectra, yet it has hitherto remained necessary to search through original papers or to calculate the positions of bands from the tables of derived constants in order to identify a given system of bands. This task is usually tedious and sometimes impossible to one without considerable experience.

Originally we prepared for use in the laboratory a list of the wave-lengths of the heads of a limited number of band systems which we frequently encountered as impurities in the course of spectroscopic research. This has proved so useful that it seems worth while to extend the list to cover, as far as possible, all known band systems. Since it appears, moreover, that such a list can be of service, not only to pure spectroscopists, but also to those who use spectroscopy as a tool for research in other fields such as astrophysics, chemistry and chemical technology, we have ventured to gather together in book form such information about known band spectra as may assist in their identification.

In the first list the bands were given in order of wave-length ; all bands of the systems considered being included. This arrangement was soon found to possess practical disadvantages. A more useful arrangement was obtained by dividing the data into two sections. The advantages of the division are discussed in the introduction preceding the tables.

As a first stage in the compilation of the available data we have been obliged to limit the scope of the tables in several directions. Thus there are limits to the range of spectrum considered and to the complexity of the molecules whose spectra are included. The wave-length region considered is from 10,000 A to 2,000 A, that is roughly from the photographic infra-red to the ultra-violet limit of quartz spectrographs, except that in a few cases, where the origin of a system lies near the border line, one or two bands have been included which are just outside this range. As to complexity we have endeavoured to include all recorded systems of diatomic molecules, but only those of triatomic and more complex molecules which show well-defined banded structure and are of frequent occurrence in spectroscopic investigations. The absorption spectra of complex organic molecules and of solutions have been omitted.

In addition to the wave-lengths of the band heads, the tables include information about the appearance and occurrence of each band spectrum. Though the information thus given is often useful for reference for other purposes, the object of identification has been kept foremost throughout in making decisions relating to the selection and arrangement of material.

For some systems we have found that the existing data are very incomplete. Where these systems are of frequent occurrence we have made new wave-length measurements. In a large number of cases where no estimates of intensities are given in the original paper, but a photograph is included, we have included estimates of intensities made from the photograph. In other cases where the analysis alone is

given without mention of the positions and intensities of the most prominent heads, we have located the positions of the heads from the analysis where possible, and if necessary converted the corresponding wave-numbers to wave-lengths. In this connection we should like to point out that it would be of great assistance for purposes of identification if authors of papers reporting new band systems would always in future include a brief description of the appearance of the system with wave-lengths and intensities of the strongest heads, a few notes on the sources with which it is obtained, and, if possible, publish a photograph with a wave-length scale or a comparison spectrum.

In addition to photographs which we have taken ourselves, we have been very fortunate in having access to numerous spectrograms taken by Professor A. Fowler and his colleagues and students in the Astrophysics Department of the Royal College of Science. Several of the reproductions of common band spectra have been taken from these plates.

Finally, it is with pleasure that we acknowledge our indebtedness to the late Professor A. Fowler for a thorough introduction to the study of spectroscopy and for turning our attention to many of the spectra dealt with herein; to Professor H. Dingle for interest and encouragement in the preparation of these tables; to Dr. W. Jevons, Dr. R. W. Lunt, Dr. E. C. W. Smith, Mr. R. F. Barrow and Mr. R. C. Pankhurst for the use of spectrograms and unpublished data as well as for useful criticism during trial of the tables, and to Mr. E. S. Parke for very valuable assistance in the preparation of the plates. One of us (A. G. G.) is also indebted to the Trustees of the Beit Fellowships for Scientific Research for a special grant, during the tenure of which a large part of the manuscript was compiled.

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INTRODUCTION

Experience in using the list of band heads arranged in order of wave-length showed that in extending it to include many more molecules a modification of form was desirable. The Tables for the Identification of Molecular Spectra are therefore divided into two sections.

The first section consists of a list of the strongest heads of the more persistent and better known band systems of each molecule in order of wave-length, together with information as to origin, intensity in various sources, and appearance.

The second section consists of individual lists of band heads for each system of each molecule, accompanied by notes about the occurrence and appearance of the system, the nature of the electronic transition involved, the vibrational assignment of the bands in the system, and references to the sources of the data. The lists are arranged in alphabetical order of the chemical symbols of the molecules.

The general considerations leading to this division are briefly as follows. For practical reasons it is preferable to identify the molecular contribution to a given spectrum system by system, rather than band by band. It is the practice to identify the atomic contribution line by line with the aid of tables of atomic lines in order of wave-length and there is a natural tendency to proceed to identify bands in a similar way. Such a procedure, however, frequently leads to incorrect identification. In an atom each change of electronic state gives rise to a line, whereas in a molecule each change of electronic state gives rise to a band system. The various bands of the system arise from changes of the vibrational state of the molecule and in general involve much smaller energy intervals than the electronic changes. Thus in respect of variation of intensity from source to source the bands of one system behave somewhat like the components of a fairly close multiplet, appearing and disappearing together. But whereas the multiplet contains relatively few lines of the whole spectrum, a single band system often contains several hundred bands and may comprise all the radiation that is readily excited for that particular molecule. Inclusion of all such bands in a single list leads to a large number of coincidences in wave-length which are merely fortuitous. Such coincidences are more troublesome in the case of bands than in the case of lines, since the wave-length recorded for a band head depends very considerably on the judgment of the observer and the dispersion used. This makes it much less safe to identify a single band by wave-length alone than it does to identify a single line in this way. Supporting evidence should always be sought. Such evidence can be obtained by considering the system as a whole. The list of Section I has therefore been restricted to a few of the strongest bands of each system so that it is somewhat analogous to the list of persistent lines of the elements. The actual number and choice of bands which should be included in this list is mainly a matter for experience to decide. The purpose of the list is to provide a clue to the identity of an unrecognised system. The strongest band of the unknown system is compared with the list, and a close agreement of wave-length and direction of degradation may suggest that it is a member of a certain system of a given molecule. Reference is then made to the individual list for that system and the presence or absence of other members checked. The process is then continued with the strongest of the remaining unidentified bands, and

so on. It is also advisable to look for other systems of the molecules for which systems are found as well as for systems of other molecules containing the same elements. Thus if a system of C_2 is found and a system of N_2, it is well to look for systems of CN as well as for other systems of N_2 and C_2. Or, again, if a trace of oxygen is suspected, systems of NO and CO may be looked for. This procedure often leads to the discovery of weak bands, masked by stronger bands, which would otherwise have passed unnoticed. In following up other systems in this manner, and indeed in all cases where interest lies in the spectrum of a given molecule, the arrangement of Section II is especially convenient. It is well also to emphasise that the evidence of atomic lines should not be neglected.

To facilitate the checking of the presence of atoms a table of persistent lines of the elements has been included in the appendix. If it is desired to check the line spectra more fully, recourse should be had to the various tables of atomic lines that are available.

Finally, inasmuch as direct comparison of photographs is the quickest and most certain way to identification, a number of plates are included showing many of the more frequently encountered band systems.

TABLE OF PERSISTENT BAND HEADS

THE object of this table is to provide a clue to the nature of the unknown band system as quickly as possible, so that it may be compared directly with the appropriate detailed list. For this purpose it contains, for all suitable band systems of frequent occurrence, a selection of the outstanding heads, which are most conspicuous under various conditions of excitation, arranged in order of wave-length. The actual number of bands of a system included is somewhat arbitrary, and the optimum can only be decided by extensive trial of the list. The general considerations are that there should be sufficient bands to provide a clue, whether the system is observed in emission or absorption, but not so many as to multiply unduly the possibility of chance coincidences. In a great number of cases, when the band system is composed of well-marked sequences, the requirements are well fulfilled by giving the first heads of the (1, 0), (0, 0) and (0, 1) bands. In other cases, however, where the molecular constants differ greatly for the two electronic states involved, the strongest bands are often far from the system origin and, moreover, those which are conspicuous in emission are weak in absorption, and *vice versâ*. The Schumann-Runge bands of O_2 may be quoted as an extreme example of this behaviour. Then, again, the nature of the overlapping background of band structure decides to a considerable extent how conspicuous is a given head. Thus, the first head of a sequence is usually more outstanding than a slightly stronger head further along the sequence on account of greater contrast with the background and so is given preference. Similarly, in the case of close double or triple heads, it is usually the first head which is included in the list. In difficult systems the best selection can only be made from a series of photographs taken under various conditions. However, even if the absence of such photographs has in a few cases caused the omission of the *most* conspicuous head, nevertheless the heads included should be among the outstanding ones, so that by trial of two or three heads from the unknown spectrum a coincidence should be obtained.

Wave-lengths. In the first column are given the wave-lengths in air in International Angstroms, values being quoted, where possible, to the nearest 0·1 A. Bands which are of particularly frequent occurrence as impurities are marked by an asterisk * before the wave-length. The letter R, V or M immediately following the wave-length indicates that the measurement is for the head of a band degraded to longer (red), shorter (violet) wave-lengths or is the maximum of a headless band respectively. The letter O is used in a few cases to signify that the wave-length recorded refers to the origin of the band.

Intensities. Intensities are eye estimates based on a scale of 10 for the strongest band of the system (or in a few cases for the strongest band of all the systems of that particular molecule), and they therefore usually refer only to the relative intensities of the bands within the system. Intensities printed in ordinary type are derived from actual experimental observations on the given source. Intensities given in italics are estimates based on consideration of the vibrational distribution of intensity in other sources and imply that the band has been observed in the given source, but the observer has omitted to record intensities. Absence of a figure for intensity in any particular column merely indicates that the authors have no knowledge of the occurrence of the

system in that source, but a dash, —, denotes that under normal experimental conditions the band is unlikely to occur in that source (*e.g.*, a band arising from a transition between two excited electronic states will not in general be observed in absorption at ordinary temperatures).

Sources. Intensities are listed for the following sources :—

Ab.	Absorption in vapour state.
F.	Emission in flame.
A(a).	Emission in an arc at atmospheric pressure, usually in air.
A(r).	In an arc at reduced pressure (frequently referred to as a vacuum arc). Bands occurring in arc sources are listed under only one of these (a) or (r), that which is more favourable to the band.
D^+ / D^-	In discharge tubes of various sorts. The + and − columns denote whether the band appears more readily in the positive column or the negative glow respectively. Bands occurring in special discharges such as a high-frequency electrodeless discharge are usually listed in the positive column with an additional note under " Occ."

Appearance. Some indication of the appearance of the band is given in the last column but one, the following abbreviations being used :—

CD.	Close double head (separation $\frac{1}{4}$–2 A.).
CT.	Close triple head (separation $\frac{1}{4}$–2 A.).
D.	Double head (separation 2–15 A.).
DCD.	Double head, each component a close double.
F.	Group of four or five heads.
Fd.	Group of five heads appearing double with small dispersion.
L.	Narrow band resembling an atomic line.
S.	Head of a sequence or group of bands.
T.	Triple head (separation 2–15 A.).
wr.	Accompanied by weaker head to the red.
wv.	Accompanied by weaker head to the violet.

Occurrence. In the last column headed " Occ." some indications are given of special conditions or sources which are particularly favourable to the production of the band, the following abbreviations being used :—

c.	Mildly condensed discharge.
e.	Controlled electron source.
f.	Fluorescence.
hf.	Electrodeless high-frequency discharge.
r.	Ring discharge.
t.	Tesla coil.
A.	Favoured by presence of argon.
H.	,, ,, hydrogen.
He.	,, ,, helium.
N.	Excited by active nitrogen.
Ne.	Favoured by presence of neon.

Very Extensive Systems. Some systems comprise a very large number of bands which differ little in intensity and cover a wide range of the spectrum. Because of

the large number of bands which would have to be included for identification in the list of persistent heads they have in many cases been omitted. The extensive character of these systems in itself provides a clue to their identity.

The following is a list of the most important molecules which emit such extensive systems with the approximate region of the spectrum covered. Unless stated to the contrary, all these systems consist of bands degraded to longer wave-lengths (red).

As_2	4300–2250 A.
Br_2	> 8000–5100.
CO flame (narrow headless)	6000–3000.
Cl_2	> 6000–4800.
CsH	6500–5000.
H_2	"many-line."
I_2	> 8000–5000.
IBr	> 7000–5500.
ICl	> 8000–5700.
K_2	8900–7700, 7000–6200, 4500–4200.
KH	5500–4000.
Li_2	7700–6600, 5000–4700
LiH	5000–3000.
Na_2	7000–6000, 5100–4800, 3500–2500.
NaH	5000–3700.
NaK	9100–7200, 6000–5700, 5300–4900, 4000–3800.
P_2	3300–2000.
Rb_2	7100–6700, 5200–4500.
RbH	6500–5000.
Se_2	3700–3000.
Te_2	4900–3900.

The following molecules show extensive systems which are partly included in the table of persistent heads :—

CN	"Cyanogen red," 9400–4700.
CO	"Fourth Positive," 2800–< 2000.
N_2	"First Positive," > 10000–5000.
O_2	"Schumann-Runge emission," 4400–3000.
O_2^+	"Second Negative," 6000–2000.
S_2	6000–2800.
SO_2	absorption 3400–2500.
SiF	6500–2500 (bands degraded both ways).
SiO	3000–< 2000.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
10603·3 R				10	*10*		BaH			
10420 V					10		N_2	1st Positive	T.S.	
10052 R				10	*10*		BaH			
*9834·7 V			10				CaO		S.	
9420 O	*9*						H_2O			
*9229 V			8				CaO		S.	
9060 O	*6*						H_2O			
9017 R				10	*10*		BaH			
8924 R				10	*10*		BaH			
*8911·6 V	—	—			10		N_2	1st Positive	T.S.	
*8722·3 V	—	—			8		N_2	1st Positive	T.	
*8651·9			8				CaO			
8571·5 R		*7*	7				BaF		S.	
8563 O	*5*						HCN			
*8541·8 V	—	—			6		N_2	1st Positive	T.	

		Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*8406·0	R			1				LaO		S.	
8297	R		8	*8*				FeO			
8228	R		8	*8*				FeO			
8227	O	*8*						H_2O			
*8153·0				10				CaO			
8137	R		8	*8*				FeO			
8137·0	R		*7*	7				BaF		S.	
8106	R		10	*10*				FeO			
7952	R			10				BeO			
7919	M	*9*						NH_3			
7912	O	*8*						HCN			
*7910·5	R			8				LaO			
7879·3	R			*10*				CeO			
*7877·2	R			6				LaO		S.	
7852·5	V	—	—			3		C_2	High Pressure	D.	c.
7833·9	R	—	—			3		CO	Asundi	T.	
7831·8	R			*10*				CeO		S.	
7828·0	R			8				TiO	γ		
*7753·2	V	—	—			6		N_2	1st Positive	T.S.	
*7715·7				4				CaO			
7672·1	R			8				TiO	γ		
7628·1	R			7				TiO	γ		
*7626·2	V	—	—			7		N_2	1st Positive	T.	
7593·7	R	10	—	—				O_2	Atmospheric		
7589·6	R			7				TiO	γ	S.	
7508	V				10	*10*		SrH			
*7503·9	V	—	—			7		N_2	1st Positive	T.	
*7403·5	R			10				LaO			
*7386·6	V	—	—			5		N_2	1st Positive	T.	
*7379·8	R			8				LaO		S.	
7348·0	V				10	*10*		SrH			
7346·7	V				10	*10*		SrH			
*7318·5				2				CaO			
7297·2	R			*10*				CeO		S.	
7275·5	R			*10*				CeO			
7235·8	R			*10*				CeO		S.	
7227	O	*5*						H_2O			
7210·4	R	—	—			5		CO	Asundi	T.	
7197·7	R			7				TiO	γ		
7125·6	R			10				TiO	γ		
7116·0	R	10	*8*	8				BaF		D.S.	
7087·9	R			9				TiO	γ		
7083·2	V	—	—			4		C_2	High Pressure	D.	c.
7054·5	R			7				TiO	γ	S.	
7018·1	V				10	*10*		SrH			
7011·0	V	10						SrI		S.	
*6994·5	R			1				LaO		S.	
6984·7	V				10	*10*		SrH			
6942·6	V				10	*10*		CaH			
6930·2	V	10						SrI		S.	

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*6927·6 R		2	2		2		CN	Cyanogen Red	T. wv.	N.
6867·2 R	8	—	—				O_2	Atmospheric		
*6856·3 V	—	—	—			*8*	O_2^+	1st Negative		
6850·2 V				10	*10*		BaH			
6847·7 V	10						SrI		S.	
6804·0 R	—	—			8		CO	Asundi	T.	
*6792·5 R		1	2		2		CN	Cyanogen Red	T. wv.	N.
*6788·6 V	—	—			6		N_2	1st Positive	T.	
6782·8 R		*8*	8				BaO			
6767·8 V	10						SrI		S.	
*6704·8 V	—	—			8		N_2	1st Positive	T.	
6689·5 V				10	*10*		BaH			
6685·7 R	—	—			7		CO	Asundi	T.	
6666·7 V	10	10					SrBr		S.	
6655·6 V	*7*	*7*	7				SrF		S.	
6651·5 R			4				TiO	γ	S.	
6632·7 V	10	*10*	10				SrF		S.	
*6631·6 R		4	9		9		CN	Cyanogen Red	T. wv.	N.
*6623·6 V	—	—			9		N_2	1st Positive	T.	
*6620·3 V	—	—			7		CO	Angstrom		
6619·9 V	4	*1*	5				SrCl		S.	
6613·7 V	10	*10*	10				SrCl		S.	
*6544·8 V	—	—			10		N_2	1st Positive.	T.	
6543·0 R			5				ZrO	γ		
6533·5			9				SmO			
6518·6 R					10		F_2			
6513·5 R	—	—			9		CO	Asundi	T.	
6513·0 V	5	10					SrBr		S.	
6512·0 V	10	*10*	10				SrF		S.	
6510·9			10				SmO			
6508·1 R			9				ZrO	γ		
6493·4 R			1				CuO			N.
6493·1 R		*9*	9				BaO			
6492 V					*5*		SiF	ξ		
*6478·7 R		9	10		10		CN	Cyanogen Red	T. wv.	N.
6473·7 R			10				ZrO	γ		
*6468·5 V	—	—			10		N_2	1st Positive	T.	
6464·6 R	—	—			10		CO	Triplet		He. H.
6451·5 R		*7*	7				CrO			
6446·2 R			5				ScO			
6442·3 V	—				6		C_2	High Pressure	D.	c.
6435 V					10		FeBr			hf.
6433·1 R	—	—			10		CO	Triplet		He. H.
6430·0 R			3				CuO			N.
6419·0 V		*8*	8				SrF		S.	
*6418·7 V	—	—	—		*9*		O_2^+	1st Negative		
6416 V					*5*		SiF	ξ		
6412·9 V	10	7					CaI		S. wr.	
6412·3 R			6				ZrO	γ		
6400·4 R		*1*	5				CuO			N.

		Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
6400	R					10		FeBr			hf.
6399·0	R	—	—			10		CO	Triplet	CD	He, H.
6398·7	R	—	—	—	—	10		He_2			c.
6397	V					*5*		SiF	ξ		
*6394·7	V	—	—			9		N_2	1st Positive	T.	
6394·3	R		*9*	9				CrO			
6389·3	V				10	*10*		CaH		D.	
6388·8	V	10	10					CaI		S. wr.	
6378·3	R			8				ZrO	γ		
6376·9	R			2				CuO			
6368	R	10	—	—	—	—	—	O_2	Liquid		
6366·9	R	—	—			5		CO	Asundi		
6362·4	V	*4*	*4*	5				SrCl		S.	
6361·3	V	6	3					CaI		S. wr.	
6358·7	V	10	10	10				SrCl		S.	
6349·5				8				SmO			
6344·9	R			9				ZrO	γ		
6342·2	R		8	8				NiO			
*6332·2	R		10	9		9		CN	Cyanogen Red	T. wv.	
*6322·9	V	—	—			7		N_2	1st Positive	T.	N.
6311·7	V			4				MgO			
6306·1	V		*8*	8				SrF		S.	
6294·0	R		*2*	5				CuO			N.
6292·8	R			7				ZrO	γ		
6291·0	R		*8*	8				BaO			
6286·0	V	0	4					CaBr		S.	
*6285·3	V		*3*	3				CaF		S.	
6278	V			4				CaO ?			
6277·7	V	10	10					CaBr		S.	
6276·6	R	3	—	—				O_2	Atmospheric		
6265·9	V					8		NBr			N.
6260·9	R			8				ZrO	γ		
6258·8	V	0	5					CaBr		S.	
6258·5	V			9				CaO ?			
*6256·6	V		*4*	4				CaF		S.	
6252·9	V	10	10					CaBr		S.	
*6252·8	V	—	—			3		N_2	1st Positive	T.	N.
6250·7	R	*1*		8				PbO	A.		
6246·0	R		10					NiH			
6244·0	R	—	—			5		CO	Asundi	T.	
6238·7	R	—	—	—			7	CO^+	Comet Tail	wv.	
6231·1	V					8		NBr			N.
6229·4	R			9				ZrO	γ		
*6224·9	V	*5*	5	5				CaCl		S.	
6218·9	R		10	*10*				FeO			
6218·3	R		*8*	8				BiO			
6211·6	V	*10*	10	10				CaCl		S.	
6193·4	V	*5*	5	5				CaCl		S.	
*6191·7	R		6	2		4		CN	Cyanogen Red	T. wv.	N.
*6191·2	V		4	*3*		3		C_2	Swan	S.	c.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
6189·4 R	—	—	—			7	CO^+	Comet Tail	wv.	
6187 M					8		FeBr			hf.
*6184·9 V	*10*	10	10				CaCl		S.	
6180·5 R		9	*9*				FeO			
6161·5 R		*9*	9				CuO			N.
*6157·4 R			1				LaO		CD. S.	
6154·9 R		*7*	7				MnO		S.	
6146·8 R		*4*	8				CuO			N.
6133·3 R		8	8				NiO			
6132·1 R			10				YO		S.	
*6122·1 V		3	*4*		4		C_2	Swan		c.
6117·5 V				5			BiH			
6115·2 V						6	As_2^+			
6109·9 M		9	*9*				FeO		L.	
6105·2 R	—	—			5		CO	Asundi	T.	
6102·6 R					10		F_2			
6097 V			10				CaO ?			
6097·3 M		9	*9*				FeO		L.	
6096·8 R			8				YO		S.	
*6086·9 V		*5*	5				CaF		S.	
6086·4 R			8				VO			
*6079·9 V	—	—	—		8		CO	Angstrom		
6079·3 R			8				ScO			
6072·6 R			8				ScO			
*6069·7 V	—	—			7		N_2	1st Positive	T.	
*6064·4 V	8	*10*	10				CaF		S.	
6064·3 R			7				ScO			
6064·0 V					10		FeCl			hf.
6060·3 V			6				MgO			
*6059·7 V		3	*3*		3		C_2	Swan		c.
6059·3 R		*10*	10				CuO			N.
6051·6 R		*10*	10				CrO			
*6050·8 V	5	*4*	6				CaF		S.	
6045·1 R		*4*	9				CuO			N.
6039·6 R		*9*	9				BaO			
6039·1 R	*0*	4	*7*		*7*		S_2			
6037·0 R	—	—	—		8		CO	Triplet		He. H.
*6036·9 V	8	*7*	6				CaF		S.	
6036·2 R			10				ScO			
6035·2 R		*10*	10				BiO			
*6026·4 V	—	—	—			*10*	O_2^+	1st Negative		
6019·5 V					9		NBr			N.
6017·1 R			6				ScO		S.	
*6013·6 V	—	—			7		N_2	1st Positive	T.	
6010·5 R	—	—	—		8		CO	Triplet		He. H.
*6006 V			8				CaO ?			
*6004·9 V		2	*3*		3		C_2	Swan		c.
*6003 R			8				CaO ?			
5998·9 O	—	—				10	NO^+			
5993·8 V					8		BF			hf.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*5992·6 R		2	5		6		CN	Cyanogen Red	T. wv.	N.
5992·6 V						9	As_2^+			
5990·7 V					10		NBr			N.
*5983 R			8				CaO ?			
5980·7 R	—	—	—		8		CO	Triplet		He. H.
5972·2 R			10				YO		S.	
5962·4 V					10		NBr			N.
5962·2 R	*0*	5	*6*		*6*		S_2			
*5959·0 V	—	—			8		N_2	1st Positive	T.	
*5958·7 V		1	*2*		2		C_2	Swan		c.
5939·1 R			8				YO		S.	
*5934·0 R	*10*	10	10				CaCl		S.	
5933·8 V					10		NBr			N.
5931·9 R		*8*	8				BiO			
5910·7 R	*3*		10				PbO	A		
*5906·0 V	—	—			8		N_2	1st Positive	T.	
5905·0 V					10		NBr			N.
5900·7 R	*0*	7	*9*		*9*		S_2			
5899·3 V	—	—			8		C_2	High Pressure	D.	c.
5887·4 R			3				ScO			
5868·1 R		9	*9*				FeO			
*5866·3 R			4				LaO		CD. S.	
5864·5 R		*10*	10				BaO			
5861·7 R		*10*	10				BiO			
5861·0 R	—	—	—		6		CO	Asundi	T.	
5859·6 R		9	9				MnO		S.	
*5858·2 R		2	8		9		CN	Cyanogen Red	T. wv.	N.
*5854·4 V	—	—			8		N_2	1st Positive	T.	N.
5849·1 R			3				ScO			
5847·7 R			3				ScO			
5847·6 R			3				CuO			
5842·0 R			4				YO		S.	
5840·6 R	*0*	7	*9*		*9*		S_2			
5837·5 V					8		CoCl			hf.
5832·7 R			2				CuO			
*5830 R	0	*4*	5				CaF			
5826 R	9	—	—	—	—	—	O_2	Liquid		
5822·1 V					10		BF			hf.
5815·1 V					8		BF			hf.
*5809·9 R	*3*	4	4				CaCl			
5809·8 R			3				ScO			
*5804·3 V	—	—			7		N_2	1st Positive	T.	N.
5801·4 M					8		FeCl			hf.
5794·4 R		*8*	8				CrO			
5789·8 R		9	*9*				FeO			
5779·5 R	7	*8*	8				SrF			
5778·5 R			5				ZrO	β		
5775·5 V			5				MgO			
5772·0 R	7	*8*	8				SrF		S.	
5763·4 R		*9*	9				PrO		S.	

	Ab.	F.	A(a).	A(r)	D+.	D−.		System.	App.	Occ.
5758·6 R			4				TiO	α	CT. S.	
*5755·2 V	—	—			7		N_2	1st Positive	T.	N.
5749·1 R	—	—	—		6		CO	Asundi	T.	
5748·1 R			8				ZrO	β		
5737·9 M					10		CoCl			hf.
5736·7 R			10				VO			
5733·0 V	—	—	—	—	9		He_2			c.
5731·4 R					9		F_2			
*5730·2 R		5	8		7		CN	Cyanogen Red	T. wv.	N.
5724·0 R			6				ZrO	β		
5718·6 V					8		NBr			N.
5718·1 R			10				ZrO	β		
5712·5 R		8					NiH			
5710·1 R	*0*	7	*8*		*8*		S_2			
5701·0 R		*8*	8				BaO			
5698·0 R			4				HfO		S.	
5697·8 R			5				YO		S.	
5695·1 V					8		NBr			N.
5694·3 V	8	*8*					CuF	A.	S.	
5691·0 R		*10*	10				PrO		S.	
5677·8 R	*5*	10	10				PbO	A.		
5677 V					10		MnH			
5670·5 R	—	—	—		6		CO	Triplet		He. H.
5668·2 M					10		CoCl			hf.
*5653.1 V	—	—	—			2	N_2^+	1st Negative		He.
5651·6 R	*0*	7	*10*		*10*		S_2			
5647·6 R	—	—	—		6		CO	Triplet		He. H.
5644·1 R		*9*	9				BaO			
5637·4 R					10		CoBr			hf.
*5635·5 V		9	*8*		8		C_2	Swan	S.	c.
*5631·9 V	—	—	—			*9*	O_2^+	1st Negative		
5629·3 R			6				TiO	β	CD.	
5629·0 R			6				ZrO	β		
5621·7 R	—	—	—		6		CO	Triplet	CD.	He. H.
5614·0 R		6	*6*				FeO			
*5610·2 V	—	—			10		CO	Angstrom		
5609·5 V	10	10					BaI			
*5599·9 R			10				LaO		CD. S.	
*5598·3 R		3	3		3		CN	Cyanogen Red	T. wv.	N.
5597·8 R			7				TiO	β	CD. S.	
5596·6 R		*8*	8				PrO			
5586·4 R		*10*	10				MnO		S.	
*5585·5 V		8	*8*		8		C_2	Swan		c.
5582·8 R		6	*6*				FeO			
5567·0 R			8				TaO			
5563 R			10				PbH			
5551·7 R			5				ZrO	β		
5547·6 R			4				BiO			
5547·5 R			7				BO	α	CD.	N
*5540·7 V		5	*6*		6		C_2	Swan		c.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
5529·5 R		8	8				NiO			
5528·3 R					9		CoBr			hf.
5518·8 V			4				MgO			
*5515·6 V	—	—			2		N_2	1st Positive	T.	
5506·5 R			*10*				SbO			
*5501·9 V		3	*4*		4		C_2	Swan		c.
5499·9 R	—	—	—			6	CO^+	Comet-tail	wv.	
*5498 R			10				CaO ?			
5497·1 R			5				TiO	α	CT.	
5492·7 R		*9*	10				BaO			
*5478·5 V	—	—			2		N_2	1st Positive	T.	
*5473·3 R		2	5		5		CN	Cyanogen Red	T. wv.	N.
*5473 R			9				CaO			
5472·8 R	*0*	7	*9*		*9*		S_2			
5469·3 R			9				VO			
5461·4 R	—	—	—			6	CO^+	Comet-tail	wv.	
5459·4 R	*8*	10	10				PbO	A.		
5456·8 R					8		BF			hf.
5448·3 R			7				TiO	α	CT. S.	
5443·4 R	10						$TeCl_2$			
*5442·3 V	—	—			3		N_2	1st Positive	T.	N.
5434·9 V	—	—			3		C_2	High Pressure	D.	c.
5418·8 R	*0*	7	*8*		*8*		S_2			
5410·5 R			3				AlO			
5407·7 R		8	8				NiO			
*5407·1 V	—	—			3		N_2	1st Positive	T.	N.
5394·8 R			3				AlO			
5393·9 R					7		F_2			
5381·7 V	10	7					BaI			
*5380·4 R			2				LaO		CD. S.	
*5372·8 V	—	—			3		N_2	1st Positive	T.	N.
5364 R	4	—	—	—	—	—	O_2	Liquid		
5360·1 M	10	10	10				BaBr		S.	
5359·4 R		*8*	9				MnO		S.	
*5354·1 R		2	4		4		CN	Cyanogen Red	T. wv.	N.
5353·6 R	8						$TeCl_2$			
5352·0 R			*7*				PrO		S.	
5351·3 R	—	—	—		5		CO	Triplet		He. H.
5349·7 R		*7*	8				BaO			
5330·5 R	—	—	—		5		CO	Triplet		He. H.
5307·2 R	—	—	—		5		CO	Triplet	CD.	He. H.
5301·8 R		6					IO ?	CH_3I flame		
*5295·7 V	—	—	—			*8*	O_2^+	1st Negative		
5293·4 R	5						Bi_2			
*5291·0 R	10	*10*	10				CaF		CD. S.	
5277·8 R			*7*				SbO			
*5262·3 R	4	*4*	*4*				CuCl	A.	S.	N.
5258·2 R	5						Bi_2			
5249·7 R	*0*	8	*8*		*8*		S_2			
5240·5 R	10	10	10				BaCl		S.	

	Ab.	F.	A(a).	A(r)	D+.	D−.		System.	App.	Occ.
5240·0 R					10		AlCl			N.
*5239·3 R		2	3		3		CN	Cyanogen Red	T. wv.	N.
*5228·3 V	—	—	—			4	N_2^+	1st Negative		He.
5224·1 R	5						Bi_2			
5211 V				10	10		MgH			
5208·2 M	10	10	10				BaBr		S.	
5205·5 R					10		AuCl			N.
*5198·2 V	—	—	—		10		CO	Angstrom		
5194·2 R	*0*	8	*9*		*9*		S_2			
5185·0 R			7				ZrO ?		S.	
5174·5 R		10	10				NiO			
*5172·6 R				*5*	5		SiN		D.	N.
5166·9 R			7				TiO	α	CT. S.	
*5165·2 V		10	*10*		10		C_2	Swan	S.	c.
5162·3 R	*3*	*9*	10				PbO	β		
5155·9 R					8		AuCl			N.
*5148·8 V	—	—	—			5	N_2^+	1st Negative		He.
*5145·4 R		*2*	2				CaF		CD. S.	
5141·1 R	*6*	*7*			7		CuI	A.	S.	N.
5138 M	10	10	10				BaCl		S.	
*5129·3 V		*7*	6		6		C_2	Swan		c.
5125·9 R		6					IO ?	CH_3I flame		
5121·9 R					8		AuCl			N.
5102·1 R			5				AlO			
*5097·7 V		2	*1*		1		C_2	Swan		c.
5096·7 R			4				ScO			
5081·0 M					10		MnBr			hf.
5079·3 R			4				AlO		S.	
5074·7 R			8				HfO		S.	
5072·8 R	*10*	*10*			10		CuI	A.	S.	N.
5072·1 R	—	—	—			5	CO^+	Comet-tail	wv.	
5070·9 R	—	—	—		8		CO	Triplet		He. H.
5061·1 V	9	*9*					CuF	B.	S.	
5060·1 R					5		N_2	Vegard-Kaplan		e.
*5053·6 V	—	—			2		N_2	1st Positive	T.	N.
5052·7 R	—	—	—		8		CO	Triplet		He. H.
5040·1 R			6				BO	α	CD.	N.
5039·7 R	—	—	—			5	CO^+	Comet-tail	wv.	
5038·8 M					10		MnCl			hf.
5036·2 R	*0*	9	*9*		*9*		S_2			
5031·7 R	—	—	—		8		CO	Triplet	CD.	He. H.
*5030·8 V	—	—			2		N_2	1st Positive	T.	N.
5019·7 R	*8*	*7*			7		CuI	A.	S.	N.
5013·2 R					8		NiCl			hf.
*5007·3 V		*10*	10				MgO		S.	
5000·6 R	2		5				BaF		S.	
*4996·7 V		*8*	9				MgO			
4993·5 R					8		MnBr			hf.
4992·1 R	2		5				BaF		S.	
4990·8 V				10			BeH			

	Ab.	F.	A(a).	A(r).	D+.	D−.	System.		App.	Occ.
4989·5 R	*0*	9	*8*		*8*		S_2			
4983·8 R	*5*	10	10				PbO	B.		
*4982·2 R	4	*5*	*5*				CuCl		S.	N.
4954·6 R			6				TiO	α	CT. S.	
4950·8 R	4		10				BaF		S.	
*4946·1 R	4	*5*	*5*				CuCl	C.	S.	N.
*4935·8 R		1	2		2		CN	Cyanogen Red	T. wv.	N.
4932·0 V	10	*10*	*10*				CuF	C.	S.	
4910·9 R	—	—	—			6	CO^+	Comet-tail	wv.	
4892·2 R		7					GdO		S.	
*4892·1 R	—	—			2		NO	β	D.	N.
4885·5 M					8		FeCl			hf.
*4881·5 R	8	*8*	*8*				CuCl	B.	S.	N.
4879·5 R	—	—	—			3	CO^+	Comet-tail	wv.	
4879·3 R	8	*8*					CuBr	A.	S.	
4866·1 R			9				AlO			
4863·2 R			*10*				CeO		S.	
4857·8 R			5				ScO			
4850·6 R		*6*	6				BaO			
*4846·9 R	8	*8*	*8*				CuCl	C.	S.	N.
4842·1 R			10				AlO		S.	
4842·1 R	*0*	9	*10*		*10*		S_2			
4838·5 R		8					IO ?	CH_3I flame		
4837·1 R					10		N_2	Vegard-Kaplan		e.
*4835·3 V	—	—	—		10		CO	Angstrom		
*4832·6 R		1	1		2		CN	Cyanogen Red	T. wv.	N.
4823·5 R	—	—	—		8		CO	Triplet		He. H.
4817·4 R			10				YO		CD. S.	
4816·9 R	*8*	10	10				PbO	B.		
*4814·7 V	—	—			1		N_2	2nd Positive	CT.	
4810·4 R			8				TaO			
4806·7 R	—	—	—		8		CO	Triplet		He. H.
4806 R			9				WO			
4804·3 R			5				TiO	α	CT.	
4802 R	3	—	—	—	—	—	O_2	Liquid		
4796·5 R		*8*	8				BiO			
4795·9 R			*9*				SbO			
4794·7 R	—	—	—		9		Cl_2^+		CD.	hf.
4794 R					5		MnH			
4791·7 R			*10*				CeO		S.	
4790·6 R	*0*	9	*9*		*9*		S_2			
*4788·5 R	5	*4*	*4*				CuCl	B.	S.	N.
4787·3 R	—	—	—		8		CO	Triplet		He. H.
4761·2 R			5				TiO	α	CT. S.	
*4755·7 R	5	*4*	*4*				CuCl	C.	S.	N.
*4752·5 V				*3*			AlH			
4751·0 R		8	8				NiO			
4751·0 R	—	—	—		9		Cl_2^+		CD.	hf.
4744·0 R			8				BO	α	CD.	N.
*4737·1 V		9	*9*		9		C_2	Swan	S.	c.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
4731·8 V				3			AlH			
4727·4 R		*10*	10				BiO			
*4723·5 V	—	—			1		N_2	2nd Positive	CT.	
*4715·2 V		8	*8*		8		C_2	Swan		c.
4711·2 R	—	—	—			5	CO^+	Comet-tail	wv.	
4709·4 R			10				WO			
*4709·2 V	—	—				4	N_2^+	1st Negative	S.	He.
4708·7 R			10				BeO			
*4705·1 R				*4*	4		SiN			N.
4698 O				10	10		BiH		wr.	
*4697·6 V		6	*7*		7		C_2	Swan		c.
4692·7 R			8				SrO			
4689·0 R				4			CuH			
4686·2 R		8					IO ?	CH_3I flame		
*4684·8 V		3	*4*		4		C_2	Swan		c.
4683·4 R	—	—	—			5	CO^+	Comet-tail	wv.	
4682·6 R	—	—	—		10		Cl_2^+		CD.	hf.
4680·2 V	—	—			10		C_2	High Pressure	D.	c.
4672·6 R			2				ScO		S.	
4672·3 R			9				LuO			
4672·0 R			8				AlO			
*4670·9 V				4	*4*		AlH			
4665·7 R		5	5				NiO			
*4664·3 R				*5*	5		SiN			N.
4661·7 R			10				LuO		S.	
4661·3 V	—	—	—		5		CO	Herzberg		
4658·0 R	*8*	8	8				PbO	B.		
*4651·8 V	—	—	—			3	N_2^+	1st Negative		He.
4649·7 R					5		N_2	Vegard-Kaplan		c.
4649·2 R			9				YO		CD. S.	
4648·4 R				6			CuH			
4648·2 R			8				AlO		S.	
4637·9 R			10				ZrO	α	CD. S.	
4633·3 R		8					GdO			
4631·4 V	*6*				7		AlI		S.	
4630·6 R					5		CuI	C.	S.	N.
4630 R	6						NO_2			
4626·1 R			4				TiO	α	CT.	
4625·6 R	—	—	—	—	6		He_2		D.	c.
4619·8 R			8				ZrO	α	S.	
4619·0 R			*10*				SbO			
4615·6 R		10					GdO		S.	
4613·8 R		*10*	10				BiO			
4613·6 R	—	—	—		9		Cl_2^+		CD.	hf.
4612·7 R			10				BO	α	CD.	N.
4609·8 R	*1*	8	*8*		*8*		S_2			
4609 R			8				WO			
*4606·1 V		1					CN	Cyanogen Violet		N.
4602·6 R	—	—	—		7		CO	Triplet		He. H.
*4599·7 V	—	—	—			4	N_2^+	1st Negative		He.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
4596·9 R					3		CuI	B.	S.	N.
4590·5 R			8				WO			
4590·2 R					10		NiBr			hf.
4586·4 R	—	—	—		7		CO	Triplet		He. H.
4585·7 R			7				BO	α	CD.	N.
4584·1 R			3				TiO	α	CT. S.	
4583·0 R		10					IO ?	CH_3I flame		
4575·1 R					4		CuI		S.	N.
*4574·3 V	—	—			2		N_2	2nd Positive	CT.	
*4574·0 R	—	—			5		NO	β	D.	N.
4569·9 R		*9*	9				BiO			
*4569·8 R				*4*	4		SiN			N.
4569·2 R	—	—	—		7		CO	Triplet	CD.	He. H.
4565·8 R	—	—	—			8	CO^+	Comet-tail	wv.	
4565·0 V	*10*				10		AlI		S.	
4564·8 R			8				SrO			
4557·3 R					8		CP	B.	wv.	A.
4553·7 R	*9*	10	10				PbO	B.		
4549·9 R		*8*	8				BiO			
4549·1 R	—	—	—		10		Cl_2^+		CD.	hf.
*4546·5 R				6	*6*		AlH			
4545·8 R	—	—	—	—	5		He_2			c.
4544·1 R			8				SrO			
4539·4 R	—	—	—			8	CO^+	Comet-tail	wv.	
4535·5 R					7		N_2	Vegard-Kaplan		e.
4534·2 R		10					BrO ?	C_2H_5Br flame		
4524·6 R					8		CP	B.	wv.	A.
*4524·3 R				*5*	5		SiN			N.
4524·0 V	*7*				7		AlI		S.	
4523·2 R	—	—			1		NH			e.
*4514·8 V			1		1		CN	Cyanogen Violet		N.
*4510·9 V	—	—	—		10		CO	Angstrom		
4507·2 R		*10*	10				BiO			
4506·8 R					7		CoCl			hf.
4506·2 R	—	—	—		8		Cl_2^+		CD.	hf.
*4502·2 V			1		1		CN	Cyanogen Violet		N.
*4502·0 R	—	—			1		NH			e.
4496·6 V	*9*				8		AlI		S.	
*4493·8 R	4	*5*	*5*		*5*		CuCl	E.	S.	N.
4493·8 R			4				ZrO	α	CD.	
4491·3 V				10	*10*		CdH			
*4490·2 V	—	—			3		N_2	2nd Positive	CT.	
4487·5 R	—	—	—		8		Cl_2^+		CD.	hf.
4486·3 R					5		CP	B.	wv.	A.
4485·0 R		7					IO ?	CH_3I flame		
*4482·4 R				*6*	6		SiN			N.
4480 M	10						NO_2			
*4479·8 R	—	—			3		NO	β	D.	N.
4477·9 R	10						CoH			
4470·5 R			2				AlO		S.	

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
4469·5 R			5				ZrO	α	CD. S.	
4465·5 R	*8*				10		BiF			hf.
4464·9 R					8		BF			hf.
4462·6 R		4					GdO		S.	
4454·7 R					6		CP	B.	wv.	A.
4448 R	8						NO_2			
*4443·1 R				*8*	8		SiN			N.
*4433·8 R	6	*7*	*7*		*7*		CuCl	D.	S.	N.
4433·4 R	*1*	9	*8*		*8*		S_2			
*4418·1 R			6				LaO		S.	
*4416·7 V	—	—			3		N_2	2nd Positive	CT.	
*4412·4 R	6	*7*	*7*		*7*		CuCl	E.	S.	N.
4412 R	10	10	*10*				SrI		S.	
4410·8 R					5		CuI	D.	S.	
4410·4 R	*10*	8	8				PbO	B.		
*4406·9 R				*8*	8		SiN			N.
4403·9 R			10				CaO			
4399·6 R			10				SrO			
4399·4 R		8					BrO ?	C_2H_5Br flame		
4393·8 R			6				AgO		D.	
*4393·1 V	—	—	—		8		CO	Angstrom		
4390 R	8						NO_2			
4384·8 R			10				CaO			
*4382·5 V		2	*2*		2		C_2	Swan	S.	c.
4380·3 V	—	—	—		7		CO	Herzberg		
4372·0 R	—	—		8			O_2	Schumann-Runge		
*4371·9 R			4				LaO		S.	
*4371·4 V		3	*4*		4		C_2	Swan		c.
4368·8 V	—	—			5		C_2	High Pressure	D.	c.
4368·2 R					10		SiF	α		
4366·7 R			9				CaO			
4366·7 R	*10*				10		BiF		S.	hf.
*4365·2 V		4	*5*		5		C_2	Swan		c.
4363·4 R			10				BO	α	CD.	N.
4359·9 R					4		CuI	D.	S.	N.
*4355·0 V	—	—			3		N_2	2nd Positive	CT.	
*4353·9 R	9	*9*	*9*		*9*		CuCl	D.	S.	N.
*4353·1 R				7	*7*		AlH			
4351·2 R			9				CaO		S.	
4350 M	6						NO_2			
*4343·6 V	—	—			4		N_2	2nd Positive	CT. S.	
4341·1 R	10	*10*	*10*				CuBr	B	S.	
4339·4 R			8				BO	α	CD.	N.
*4333·2 R	10	*10*	*10*		*10*		CuCl	E.	S.	N.
4331·6 R					10		BH		L.	
*4317·6 R				*5*	5		SiN			N.
4316·0 R	—	—	—		7		Cl_2^+		CD.	hf.
4315·0 V		3		3	3		CH			
4312·5 V		10		10	10		CH			
4310·8 R	*1*	9	*8*		*8*		S_2			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
4307 R	6	10	*10*				SrI		S.	
4305·0 R					8		NiCl			hf.
4304·7 R			4				AgO		D.	
4299·1 V				10	*10*		ZnH			
4297·6 V				10	*10*		CdH			
4295·8 R	*9*				8		BiF		S.	hf.
*4293·7 R	—	—			3		NO	β	D.	N.
4291·8 R	—	—		9			O_2	Schumann-Runge		
4289 R	5	10					CaI		S.	
4288·6 R	7	*7*	*7*				CuBr	B.	S.	
*4288·2 R	—	—			3		NO	β	D.	N.
4288 R							FeH			
4283 M				*9*	9		SiO_2 ?			
4281·0 R			8				SrO			
*4280·9 R	7	*6*	*6*		*6*		CuCl	D.	S.	N.
4279·6 R				10			CuH			
*4278·1 V	—	—	—			10	N_2^+	1st Negative	S.	He.
*4277·0 R				*5*	5		SiN			N.
4274·3 R	—	—	—			10	CO^+	Comet-tail		
4272·0 R	—	—	—			10	CO^+	Comet-tail		
4269·8 R		8					BrO ?	C_2H_5Br flame		
*4269·7 V	—	—			5		N_2	2nd Positive	CT.	
4262·8 R	8	*8*	*8*				CuBr	C.	S.	
4262·8 R			6				AgO		D.	
*4259·5 R	10	*10*		10	10		AlH			
*4258·9 R	8	*7*	*7*		*7*		CuCl	E.	S.	N.
4256·6 R				*8*	8		SiO_2 ?			
4254·4 R				*7*	7		SiO_2 ?			
4252·4 R	—	—	—			8	CO^+	Comet-tail		
4252·1 R			10				HfO		S.	
4248·9 R	—	—	—			5	CO^+	Comet-tail		
4245·9 R					6		BH			
*4241·0 R	10	*10*		10	10		AlH		D.	
4240 M				*10*	10		SiO_2 ?			
*4239·1 R				*9*	9		SiN			N.
4237·0 V				10	*10*		ZnH			
*4236·5 V	—	—				9	N_2^+	1st Negative		He.
4235·5 V				*10*	10		SiO_2 ?			
4231·6 V	—	—	—			8	CO^+	Baldet-Johnson	wr.	He.
4231·5 R	—	—	—		7		Cl_2^+		CD.	hf.
4228·5 V				*9*	9		SiO_2 ?			
4227·1 V	4			4	4		BaH			
4221·9 R			9				CaO			
*4216·0 V		9	9		9		CN	Cyanogen Violet	S.	N.
4215·9 R					7		NiCl			hf.
4214·2 R	—	—		7			O_2	Schumann-Runge		
4212·9 V	—	—	—			8	CO^+	Baldet-Johnson	D.	He.
4211 R	2	10					CaI		S.	
4205·1 R			10				CaO		S.	
*4204·1 R				*10*	10		SiN			N.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*4200·7 R	—	—			4		NO	β	D.	N.
*4200·5 V	—	—			6		N_2	2nd Positive	CT.	
*4199·1 V	—	—	—			4	N_2^+	1st Negative		He.
*4197·2 V		7	8		8		CN	Cyanogen Violet		N.
4194·7 R	—	—	—		7		Cl_2^+		D.	hf.
4193·6 R	*2*	9	*8*		*8*		S_2			
4192·7 V					10		TiCl		S. wr.	hf.
*4187·9 R	6	*4*	*5*		*5*		CuCl	E.	S.	N.
4183·6 R					*10*		SbF			N.
*4181·0 V		5	7		7		CN	Cyanogen Violet		N.
4177·5 R			8				AgO		D	
4172·7 R	—	—		9			O_2	Schumann-Runge		
*4172·1 R				*6*	6		SiN			N.
4171·2 R					5		N_2	Vegard-Kaplan		e.
4167·2 R			8				SrO			
4159·5 R	—	—	—			5	CO_2			e.
4157·0 R	*2*	8	*7*		*7*		S_2		wv.	
4154·4 R			10				TaO ?			
4143·4 R			6				BO	α	CD.	N.
*4142·2 R				10	10		SiH			
*4141·8 V	—	—			5		N_2	2nd Positive	CT.	
4140·1 R	—	—	—		8		Cl_2^+		D.	hf.
4137·6 R	—	—	—			6	CO_2			e.
4135·8 V	4	*4*	*4*				BaF		S.	
4130·6 R			*9*				SbO			
*4126·6 R				*8*	8		SiN			N.
4124·8 V	—	—	—		7		CO	Herzberg		
4123·6 V	—	—	—		7		CO	Angstrom		
4123·6 R			10				AgO			
4120·8 R	—	—	—			6	CO_2			e.
4118·9 R			6				HfO			
*4116·8 R				*6*	*6*		SiN	E.		N.
4115·8 R	—	—	—			9	O_2^+	2nd Negative		He.
*4113·6 R	—	—			4		NO	β	D.	N.
4112·1 R					10		SnBr			
4110 V	10	10	*10*				MgI		S.	
4108 R	9	10					SrBr		S.	
4107·9 R	—	—	—			5	CO_2			e.
4102·3 V	—	—		9	9		C_2	Deslandres-d'Azambuja	S.	c.
4101·2 R			5				HfO		S.	
4095·4 R	—	—		10			O_2	Schumann-Runge		
4095·3 R					10		NiCl			hf.
4094·5 R			10				AgO			
4093 V	—	—			1		C_2	High Pressure	D.	c.
*4087·4 R				*8*	8		SiN			N.
4084·3 R			10				CaO		S.	
4082·4 R	—	—	—			9	O_2^+	2nd Negative		He.
4070·7 R	—	—	—			5	CO_2			e.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
4070·7 R				10			SnBr			
4068·1 V	—	—		6	6		C_2	Deslandres-d'Azambuja		c.
*4066·3 R				5	5		AlH			
*4059·4 V	—	—			8		N_2	2nd Positive	CT.	S.
4053 R	10	10					SrBr		S.	
*4050·7 R				*8*	8		SiN			N.
4048·9 R	—	—	—			5	CO_2			e.
4045·6 R	*2*	9	*8*		*8*		S_2		wv.	
4041·8 V	—	—		3	3		C_2	Deslandres-d'Azambuja		c.
4041·7 R	—	—	—		7		Cl_2^+			hf.
4035·5 R			7				BO	α	CD.	N.
4033·0 R	—	—	—		7		Cl_2^+			hf.
*4027·8 R	—	—			6		NO	β	D.	N.
4025·3 R		3		3	3		CH			
4020·6 R	—	—		9			O_2	Schumann-Runge		
4019·7 R	—	—	—			9	CO^+	Comet-tail		
4017·7 R	—	—	—			9	CO^+	Comet-tail		
4017 V					10		HgH			
*4016·8 R				*6*	6		SiN			N.
4015·0 R			5				BO	α	CD.	N.
4014·8 R					8		CP	A.		A.
4006·2 R			8				TaO			
4005·4 R				5			CuH			
3999·6 R	—	—	—			9	CO^+	Comet-tail		
*3998·4 V	—	—			9		N_2	2nd Positive	CT.	
3997·3 R	—	—	—			9	CO^+	Comet-tail		
3994·7 R					4		SiN			N.
3989·1 R	—	—	—	—	5		He_2		D.	c.
*3985·8 R				*5*	5		SiN			N.
*3984·6 R			1		1		CN	Cyanogen Violet "Tail"		N.
3973·5 V	—	—	—			9	CO^+	Baldet-Johnson	wr.	He.
3972·8 R				10			AuH			
3970·1 R			6				HfO		S.	
*3968·5 M	10	—	—	—	—	—	Ca^+	Scattered sunlight		
3961·6 R	10		*6*				SrCl		S.	
3960·9 R	—	—	—			7	CO_2			e.
3957·0 V	—	—	—			7	CO^+	Baldet-Johnson	D.	He.
3955·0 R	9						PbO	C.		
3951 R	6	10					CaBr		S.	
*3949·8 R				*4*	4		SiN			N.
*3944·7 R			2		2		CN	Cyanogen Violet "Tail"		N.
*3943·0 V	—	—			8		N_2	2nd Positive	CT.	
3940·3 R					5		N_2	Vegard-Kaplan		e.
3938·9 R	*3*	9	*8*		*8*		S_2		wv.	
3937·1 R	10		*6*				SrCl		S.	

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*3933·7 M	10	—	—	—	—	—	Ca +	Scattered sunlight		
3917 R	6	10					CaBr		S.	
*3914·4 V	—	—	—			10	N_2^+	1st Negative	S.	He.
3912·3 R	—	—		9			O_2	Schumann-Runge		
*3911·8 R				*4*	4		SiN			N.
*3909·5 R			3		3		CN	Cyanogen Violet "Tail"		N.
3896·4 R			8				TaO			
3896 M	*10*						TlI			
3893 R					5		OH +			hf.
3893·1 V	—	—	—		7		CO	Herzberg		
3889·3 R			10				GaO		S.	
3889·2 R					5		N_2	Vegard-Kaplan		e.
3889·0 R		4		4	4		CH			
*3884·3 V	—	—	—			3	N_2^+	1st Negative		He.
*3883·4 V		10	10		10		CN	Cyanogen Violet	S.	N.
3881 M	10	10	*10*				MgBr		S.	
3878·6 V		*3*	3				BaF		S.	
3877·8 R	10						PbO	C.		
*3871·4 V		8	9		9		CN	Cyanogen Violet		N.
3870·5 R	—	—	—			7	CO_2			e.
*3868·3 R	—	—			6		NO	β	D.	N.
3864 V	10	10					MgBr		S.	
*3861·9 V		6	8		8		CN	Cyanogen Violet		N.
3860·5 V				*5*			MgCl		S.	
3859·5 R	—	—	—			9	O_2^+	2nd Negative		He.
*3857·9 V	—	—	—			4	N_2^+	1st Negative		He.
*3854·7 V		4	6		6		CN	Cyanogen Violet		N.
3853·2 R	—	—	—			4	CO_2			e.
3852·2 V	—	—		10	10		C_2	Deslandres-d'Azambuja	S.	c.
3847·0 R			9				BO	α	CD.	N.
3844 M	4						HNO_2 ?			
3842·2 V				*8*			MgCl		CD. S.	
3840·6 R	—	—		10			O_2	Schumann-Runge		
3838·8 R	—	—	—			6	CO_2			e.
3837·1 R	*4*	9	*8*		*8*		S_2		wv.	
3836 M	*10*						TlI			
3832·9 R			*6*	6			SiO_2 ?			
3830·5 R	—	—	—			9	O_2^+	2nd Negative		He.
3828·0 R			6				BO	α	CD.	N.
3825·6 V	—	—		6	6		C_2	Deslandres-d'Azambuja		c.
3825 R	3	—	—	—	—	—	O_2	Liquid		
3821 R		*8*					SeO			
*3814·0 R				*2*	2		SiN			N.
3811·8 R		*5*			5		SO			
3809·9 V	10	*10*	*10*				BaF		S.	
3808 M	*10*						TlI			
*3804·9 V	—	—			10		N_2	2nd Positive	CT. S.	

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
3795·8 R	—	—	—			8	CO^+	Comet-tail		
3792 R	—	—	—			10	BH^+			
*3788·5 R	—	—			10		NO	β	D.	N.
3778·9 V				10			MgCl		CD. S.	
3778·5 V			9				GaO		S.	
3777·9 R					8		CP	A.		A.
3777·8 R	—	—	—			8	CO^+	Comet-tail		
3775·4 R			10				SbO			
3774·4 R		8	8				CaCl		CD. S.	
3768·1 R	—	—	—			10	BH^+			
3763·5 R		8	8				CaCl		CD. S.	
3760·3 R						10	HBr^+			
3758·6 R					10		SnCl		S.	
*3755·4 V	—	—			10		N_2	2nd Positive	CT.	
3753·2 R			7				CaO			
3747·2 R			8				TaO			
3741·7 R	—	—		9			O_2	Schumann-Runge		
3739·8 R	5	9	8		8		S_2		wv.	
3733·9 R	—	—	—			9	O_2^+	2nd Negative		He.
3730·5 R		5					CHO ?	Ethylene flame		
3724·9 V	—	—	—			8	CO^+	Baldet-Johnson	wr.	He.
3720·5 V					6		MnBr			hf.
3717·0 V					10		MnCl		CD. S.	hf.
3712·4 R			2				SrF		S.	
3711·2 V	—	—	—			9	CO^+	Baldet-Johnson	D.	He.
*3710·5 V	—	—			8		N_2	2nd Positive	CT.	
3708·4 V				8			MgCl		CD. S.	
3706·6 R	—	—	—			9	O_2^+	2nd Negative		He.
3701 R		10					SeO			
3697·7 R		4					CHO ?	Ethylene flame		
3693·8 R	—	—				5	BH			
3691·8 R	—	—	—			7	CO_2			e.
3685·8 V			5				MgF		CD. S.	
3681 M	10						HNO_2 ?			
3680·9 V	—	—	—		4		CO	Herzberg		
3677·8 R			8				BO	α	CD.	N.
3676·2 R		7			7		SO			
3675 V			8				CrH			
3674·1 R	—	—	—			6	CO_2			e.
3672·7 R	—	—		9			O_2	Schumann-Runge		
3665·0 R	—	—	—	—	5		He_2		D.	c.
3662·4 R	—	—				5	BH			
3661·6 R	—	—	—			6	CO_2		S.	e.
3661·3 V					5		MnCl		CD. S.	
3656·6 R			7				CaO		S.	
3654·3 R			2				HfO		S.	
3651·5 R				9			AuH			
*3647·2 R	—	—			4		NO	β	D.	N.
3646·3 R			3				SrF		S.	
3645·0 R	5	8	8		8		S_2		wv.	

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
3632·3 V				10		10	AlH^+			
3629·8 R	—	—	—			9	O_2^+	2nd Negative		He.
*3628·9 R			1		1		CN	Cyanogen Violet "Tail"		N.
3628 R	3	—	—	—	—	—	O_2	Liquid		
3628 R		1		1	1		CH			
3627·2 R					4		NH			N.
3625·7 R			8				TaO			
3621·0 R	—	—	—			7	CO_2			e.
3620·7 V			4				AgO		S.	
3617·3 R					10		SiTe			
*3614·9 V			4				LaO		S.	
3612·4 R					10		CP	A.		A.
*3612·4 R	—	—	—			1	N_2^+	1st Negative		He.
3611·9 V				10		10	AlH^+			
3609·6 R					2		NH			N.
3607·3 V	—	—		8	8		C_2	Deslandres-d'Azambuja	S.	c.
3603·7 R	—	—	—			8	O_2^+	2nd Negative		He.
3603·0 R					5		N_2	Vegard-Kaplan		e.
*3603·0 R			3		3		CN	Cyanogen Violet "Tail"		N.
3600·8 R	—	—	—			6	CO^+	Comet-tail		
3599·2 V	*7*				7		InCl			hf.
3594·2 V			10				MgF		CD. S.	
3594·1 R	*10*						ClO_2			
3592·9 V	—	—		7	7		C_2	Deslandres-d'Azambuja		c.
3591·6 R	—	—				10	HCl^+			
*3590·4 V		7	8		8		CN	Cyanogen Violet	S.	N.
3590 R		*10*					SeO		wv.	
3588·6 R		8					CHO ?	Ethylene flame		
3587·6 V	—	—		7	7		C_2	Deslandres-d'Azambuja		c.
3587·2 R	*5*	8	*8*		*8*		S_2			
*3585·9 V		6	7		7		CN	Cyanogen Violet		N.
3585·4 R			8				SnO			
3584·2 R	—	—	—			6	CO^+	Comet-tail		
*3583·9 V		5	6		6		CN	Cyanogen Violet		N.
*3582·1 V	—	—	—			6	N_2^+	1st Negative	S.	He.
*3576·9 V	—	—			10		N_2	2nd Positive	CT. S.	
*3572·4 R	—	—			10		NO	β	D.	N.
3567·0 R			10				BeCl		S.	
3565 R	—	—	—		10		OH^+			hf.
3564·0 R			9				CaO		S.	
3562·2 R	—	—	—			8	CO_2			e.
3558·4 V			8				AgO		S.	
3556·1 R					10		SiTe			
3553·5 V			10				AgO			
3551·4 R	—	—	—			8	CO_2			e.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
3548·7 R		*6*			6		SO			
3545·9 R	—	—	—			9	CO_2			e.
3541 M	10						HNO_2 ?			
*3536·7 V	—	—			8		N_2	2nd Positive	CT.	
*3535·0 R				*4*	4		SiN		D.	N.
3533·8 R	—	—	—			7	CO_2			e.
3525·5 R			7				BO	α	CD.	N.
3517·7 R	—	—	—			9	O_2^+	2nd Negative		He.
3516·1 R	—	—		8			O_2	Schumann-Runge		
3516 R				5			AgH			
3514·3 R					10		SiTe			
3511·7 V	—	—	—			7	CO^+	Baldet-Johnson	wr.	He.
3511·4 R	*10*						ClO_2			
3510·8 R	—	—	—			6	CO_2			e.
3508·2 R					8		CP	A.		A.
3507·3 R	—	—				10	HCl^+			
3503·8 R			10				SrO			
3503·4 V			4				MgF		CD. S.	
*3503·2 R	—	—	—			6	CO_2			e.
3502·7 R		8					CHO ?	Ethylene flame		
3500 V					5		HgH			
3500·4 V	—	—	—			3	CO^+	Baldet-Johnson	D.	He.
3500·3 R	*5*	8	*8*		*8*		S_2			
3499·0 V	*10*				10		InCl			hf.
3494·2 R	—	—	—			8	O_2^+	2nd Negative		He.
3493·5 V			4				AgO		S.	
*3493·3 V	—	—	—		6		CO	3rd Positive	F.	
3487·8 R					10		SnCl		S.	
3485·7 R	*8*	*10*	10				PbO	D.		
3484·5 R	6	10	*10*				SnO		S.	
3484 R		*8*					SeO		wv.	
3475·3 R	8						TlBr			
3475·0 R			10				CaO		S.	
3472·5 R		5					CHO ?	Ethylene flame		
3469·2 R			?				SbO			
3463·6 R	8						TlBr			
3459·2 R					10		CP	A.		A.
3452·4 R	9						TlBr			
3449·2 R			2				CaF		S.	
3445·2 R			6				SrO			
3441·6 R			6				BO	β		N.
3434·0 R	*10*						ClO_2			
3429·6 R	10						TlBr			
*3428·1 R		4		4	4		OH		DCD.	
3424·6 R					4		N_2	Vegard-Kaplan		
3421·2 R	—	—	—			9	O_2^+	2nd Negative		He.
3420·5 R	—	—				10	HBr^+			
3419·6 R					10		PH			
3418·2 R	9						TlBr			
3417 M	8						HNO_2 ?			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
3416·1 V					7		FeCl			hf.
3409·1 R			7				CaO		S.	
3401·9 R	*8*	*8*	8				PbO	D.		
3399·7 V	—	—		5	5		C_2	Deslandres-d'Azambuja	S.	c.
3398·1 V	—	—		5	5		C_2	Deslandres-d'Azambuja		c.
3397·8 R	—	—	—			9	O_2^+	2nd Negative		He.
3389·8 R			6				SrO			
3389 M	4						CH_2O	Formaldehyde		
3388·3 R	8	7	*7*				SnO		S.	
3387·6 R			6				BO	α	CD.	N.
3384·4 V					10		CdI			
3383·1 R		*6*			6		SO			
*3381·3 R	—	—	—			1	N_2^+	1st Negative		He.
*3377·5 R	—	—	—			10	CO_2			e.
3377·4 R		10					CHO ?	Ethylene flame		
*3376·4 R	—	—			10		NO	β	D.	N.
3374·1 M	3	—	—				O_3			
*3371·3 V	—	—			10		N_2	2nd Positive	CT.	S.
3371·1 R			2				CaF		S.	
*3370 M		10		10	10		NH		L.	
*3370·0 R	—	—	—			10	CO_2		S.	e.
3369·6 R	—	—		8			O_2	Schumann-Runge		
3369·4 R	*6*	7	*8*		*8*		S_2			
3363·5 R					10		CP	A.		A.
3363 M					10		SiF	η		
3360·5 R	*10*						ClO_2			
*3360 M		9		9	9		NH		L.	
3359·0 R		5					CHO ?	Ethylene flame		
3348·0 R	—	—	—	—	3		He_2		D.	c.
3346 M					10		SiF	η		
3338·5 M	4	—	—		8		O_3			
3332 R					5		OH^+			
3330 R				10			AgH			
3323·4 R	10	8	*8*				SnO			
3311·9 R		*8*	8		*8*		PO	β		
3311·5 M	5	—	—		6		O_3			
*3308·0 V	—	—	—			2	N_2^+	1st Negative	S.	He.
*3305·7 V	—	—	—		7		CO	3rd Positive	F.	
3305·4 R			8				BO	β		N.
3299·2 R		10					CHO ?	Ethylene flame		
*3298·7 V	—	—	—			2	N_2^+	1st Negative		He.
3297·6 R	*3*				7		SiS			
3296·4 R		*8*	8		*8*		PO	β		
3290·4 V					7		SnBr			
3288 R	6						CH_2O	Formaldehyde		
3284·3 R	—	—	—			5	CO_2			e.
3279·8 M	8	—	—		3		O_3			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
3277·2 R		*10*	10		*10*		AsO		CD.	
3274·8 M	8						CS_2			
3273·7 R					6		CP	A.		A.
3271·0 R		*10*			10		SO			
3270·5 V			10		*10*		PO	β		
3269·9 R	—	—	—			7	CO_2			e.
3268·9 R		*8*	8		*8*		PO	β		
3264·6 R	—	—	—			7	CO_2			e.
*3263·6 R	8						TlCl			
3262·4 R					10		SiSe			
3260 M	7						CH_2O	Formaldehyde		
3256·9 R			9				BO	β		N.
3255·5 M	5	—	—				O_3			
3255·3 V			10		*10*		PO	β		
3254·8 V					5		BF		F.	hf.
3253·9 R	—	—	—			8	CO_2			e.
3253·4 R			8		*8*		PO	β		
*3253·4 R	—	—				5	NH			
3253 V	—	—	—		3		CO	Knauss		r.
*3251·5 R	8						TlCl			
3249·7 M	8	—	—				O_3			
*3246·9 R	—	—	—			8	CO_2		S.	e.
3246·3 R		*10*	10		*10*		PO	β		
*3242·1 V	—	—	—		6		CO	5B	F.	
*3240·6 R	8						TlCl			
*3240·1 R	—	—			2		NH			N.
3236·6 R	8						SH			
3235 M	8						CS_2			
3234·4 V					7		SnCl			
3232·5 R	—	—		7			O_2	Schumann-Runge		
3231·2 R	—	—	—			9	O_2^+	2nd Negative		He.
*3230·8 R	9						TlCl			
3227·2 M	10	—	—				O_3			
3221·8 R	*4*				8		SiS			
3221·5 M	10	—	—				O_3			
*3221·1 R	10						TlCl			
3210·8 R	—	—	—			9	O_2^+	2nd Negative		He.
3210·0 R	*10*						AgI			
3209·3 R			7				BO	β		N.
3207·8 R		*6*	7		*7*		AsO		CD.	
3204·4 M	9						CS_2			
3203·0 R					10		SiSe			
3201·0 M	8	—	—				O_3			
3200·8 R	*8*				9		AgCl		S.	hf. f.
3199·5 R	*10*						AgBr			
*3198·0 R	—	—			10		NO	β	D.	N.
3197·8 V					7		SnCl			
3197·5 R					5		N_2	Vegard-Kaplan		

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
3194·8 M	6	—	—				O_3			
*3193·2 R	7						TlCl			
3190·2 R					8		CP	A.		A.
3189·5 M	10						CS_2			
3179 R				5			AgH			
3177·0 M	8	—	—				O_3			
3176·6 V					10		CdBr			
3170·6 R		*9*	9		*9*		AsO		CD.	
3166·2 R	*10*				10		AgCl		S.	hf. f.
3164·8 R		*10*			10		SO			
3164 R	9						CH_2O	Formaldehyde		
*3159·3 V	—	—			9		N_2	2nd Positive	CT. S.	
3156·1 M	8	—	—				O_3			
3145·3 R					9		SiSe			
3144·0 M	8						CS_2			
3143 M	8						CH_2O	Formaldehyde		
3143·4 R		1			1		CH			
3141·2 V	?						SnF			
3139·7 R	*10*				9		AgCl		S.	hf. f.
3138 V	—	—	—		4		CO	Knauss		r.
3137·4 M	10	—	—				O_3			
*3136·0 V	—	—			8		N_2	2nd Positive	CT.	
*3134·4 V	—	—	—		8		CO	3rd Positive	F.	
*3132·9 R	—	—	—		6		CO_2		S.	e.
3127·7 R	*4*				8		SiS		S.	
3122·1 V					9		BF		F.	hf.
3114·3 M	8	—	—				O_3			
3107·5 R	—	—	—			2	CO^+	1st Negative		He.
3106·4 R					9		SiSe			
3105·6 R		*6*	7		*7*		AsO		CD.	
3105·0 M	5	—	—		6		O_3			
3103·9 R	—	—		6			O_2	Schumann-Runge		
3091·5 R	*9*	8	*9*		*9*		S_2			
3089·5 M	8	—	—		10		O_3			
3088·6 R			9				BO	β		N.
*3079·9 V	—	—	—		5		CO	5B	F.	
3077 V					*7*		COS ?			
3064·1 R		*10*			10		SO			
3064·0 R	—	—	—			3	CO^+	1st Negative		He.
*3063·6 R	10	10		10	10		OH		DCD. wv.	
3062·8 R	—	—	—			9	O_2^+	2nd Negative		He.
3057·9 R	*6*				9		SiS		S.	
3047·7 V					9		SiBr			
3043·6 V					7		SnBr			
3043·6 R			9				BO	β		N.
3043·6 R	—	—	—			9	O_2^+	2nd Negative		He.
3043 V					*10*		COS ?			
3042·6 R					3		NH			N.
*3042 R	7	—	—		—		SO_2			
3035·2 R					1		NH			N.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*3034·9 R	—	—			10		NO	β	D.	N.
3033 R	7						CH_2O	Formaldehyde	wv.	
3028 V	—	—	—		3		CO	Knauss		r.
3024·6 R	*9*	7	*8*		*8*		S_2			
3023·0 R	—	—	—			2	CO^+	1st Negative		He.
*3021 R	9	—	—		—		SO_2			
3014·8 R		8					CHO ?	Ethylene flame		
3009 V					*10*		COS ?			
3009·6 R			9				BeF		CD	
3008·8 V					10		SiBr		wr.	
*3008·8 V	*0*	*4*	*4*		4		NO	γ	DCD.	
*3000 R	10	—	—		—		SO_2			
2999·7 R			7				BO	β		N.
2990·8 R	*7*				10		SiS		S.	
2990·4 R				10			SnO	Loomis & Watson		
2989·5 R	*9*	7	*8*		*8*		S_2		wv.	
2988·8 V					8		SiCl			
2987·5 R	—	—	—			9	O_2^+	2nd Negative		He.
2984·2 R	—	—	—			2	CO^+	1st Negative		He.
*2979 R	9	—	—		—		SO_2			
*2977·4 V	—	—	—		9		CO	3rd Positive	F.	
*2976·8 V	—	—			6		N_2	2nd Positive	CT. S.	
2976·2 R	1				*10*		ZnCl			hf.
2973·4 V					8		SnCl			
2970·4 V					8		SiCl			
2970·0 R	—	—	—			8	O_2^+	2nd Negative		He.
2967·1 V					6		SiF	β	D.	
*2960·2 R	10	—	—		—		SO_2			
2958·7 V					7		SiBr			
2956 V	8						ZnCl ?			
2954·2 M					10		BBr			hf.
2954·0 R	*10*	7	*8*		*8*		S_2		wv.	
2948·2 R		7					CHO ?	Ethylene flame		
2948·1 V					10		BBr			
2944·2 R					9		BBr			
2943 V					*10*		COS ?			
*2943·0 R	9	—	—		—		SO_2			
2942·6 R	5				10		ZnCl		S.	hf.
2942·2 V					8		SiCl			
*2936·7 R	8	—	—		—		SO_2			
2935·8 V					10		SnCl			
2935·7 R					9		N_2	Vegard-Kaplan		
2935·7 R					7		BBr		S.	hf.
2934 V	10						ZnCl ?			
2934·9 R			9				BO	β		N.
2931 R	10						CH_2O	Formaldehyde		
2927·9 V	?						SnF			
2926·1 R	*8*				10		SiS		S.	
2925 V	—	—	—		2		CO	Knauss		r.
2924·4 V					8		SiCl			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*2923 R	8	—	—		—		SO_2			
2921·7 R				10			SnO	Loomis & Watson		
2920·2 R	*10*	7	*8*		*8*		S_2		wv.	
2919·8 R	—	—	—			9	O_2^+	2nd Negative		He.
2911 V					*10*		COS ?			
*2905·5 R	8	—	—		—		SO_2			
2903·9 V	—	—	—		1		N_2	4th Positive	F.	c.
2901·9 R	—	—	—			8	O_2^+	2nd Negative		He.
*2898·4 R			*3*		3		SiO			
2898·1 R	—				4		C_6H_6	Benzene	S.	t.
2897·2 R	—	—	—			3	CO^+	1st Negative		He.
*2896 M	—	—	—			10	CO_2^+			
2894·4 V					6		SiF	β	D.	
2892·3 R	*10*	7	*8*		*8*		S_2			
2892·2 R			10				BO	β		N.
2890·3 R	—	—	—			8	O_2^+	2nd Negative		He.
2887·9 R	*10*	7	*8*		*8*		S_2			
*2886·7 R	9	—	—		—		SO_2			
*2885·2 R	—	—			10		NO	β	D.	N.
2883·2 R	*7*				8		SiS			
*2883 M	—	—	—			10	CO_2^+			
2882·9 V					8		SiCl			
2881·7 R			10		10		GeO		S.	
2880 V					*7*		COS ?			
*2875 R		2		2	2		OH			
*2871·6 R			*4*		4		SiO			
2868·7 R					6		AsN		CD.	
*2867 R	8	—	—		—		SO_2			
2865·8 V					8		SiCl			
2863·7 R	*8*				8		SiS		S.	
2860·0 R	*9*	5	*7*		*7*		S_2		wv.	
*2859·5 V	*1*	*6*	*6*		6		NO	γ	DCD.	
2858·1 R	—	—	—			4	CO^+	1st Negative		He.
2858·0 R		6					CHO ?	Ethylene flame		
2856·8 V					5		CCl		T. wr.	
*2852 R	9	—	—		—		SO_2			
2850·6 R			8				BO	β		N.
2844·5 R					10		CSe		D.	hf.
2843·5 V	*10*				*10*		TlF			
2839·7 R	—	—	—			10	O_2^+	2nd Negative		He.
2839 R	9						CH_2O	Formaldehyde	wv.	
2837·9 R	—				6		C_6H_6	Benzene		t.
*2833·1 V	—	—	—		10		CO	3rd Positive	F.	
*2832 R	8	—	—		—		SO_2			
2829·1 R	*9*	5	*7*		*7*		S_2		wv.	
2827·4 R		*8*			8		SO			
2823·7 R	—	—	—			9	O_2^+	2nd Negative		He.
2822·7 R	*9*				9		SiS		S.	
2820·8 R	—	—	—			5	CO^+	1st Negative		He.
*2819·8 V	—	—			1		N_2	2nd Positive	CT. S.	

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
2818·3 R					9		AlBr		CD. S.	hf.
2814·8 R				10			SnO	Loomis & Watson		
2812·3 R	—				7		C_6H_6	Benzene	S.	t.
*2811·3 R	9	8		8	8		OH		DCD. wv.	
*2810·4 V	0	1	2		2		NO	γ	DCD.	
*2810·2 R	6						Bi_2			
2809·9 R			8				BO	β		N.
2809·7 V					10		SiCl			
*2806·3 R			8		8		SiO			
2804·2 R			10		10		GeO		S.	
*2802·6 R		—			4		NO	β	D.	N.
2799·7 R					9		CO	4th Positive		
2798·8 R	9	5	7		7		S_2			
*2797 R	8	—	—		—		SO_2			
2797·1 R		5					CHO ?	Ethylene flame		
*2796·9 R	8						Bi_2			
2796·3 R					9		AlBr		CD.	hf.
2789·8 V					10		CCl		T. wr.	
2788·8 R					10		AlBr		CD. S.	hf.
2787 R	7						CH_2O	Formaldehyde		
2785·8 R	—	—	—			5	CO^+	1st Negative		He.
2784·2 R					10		AsN		CD.	
*2783·7 R	6						Bi_2			
2783 V					9		BCl		S.	hf.
2783·2 R	10				9		SiS		S.	
*2780·5 R		6	7		7		SiO			
2777·9 V	—	—	—		2		N_2	4th Positive	F.	c.
2776·7 R	—	—	—			8	O_2^+	2nd Negative	D.	He.
2769·4 R	9	5	7		7		S_2			
*2768·9 R	8						Bi_2			
2767·2 R					9		AlBr		CD. S.	hf.
*2763·3 V	0	1	2		2		NO	γ	DCD.	
2761·9 R	—	—	—			7	O_2^+	2nd Negative		He.
2760·6 R					9		N_2	Vegard-Kaplan		
2756 R	5						CH_2O	Formaldehyde		
*2755·0 R		6	6		6		SiO			
*2754·7 R		7	6		7		CS		CD.	
2753·4 R			9				BO	β		N.
2752·9 R	—	—	—			6	CO^+	1st Negative		He.
2751·2 R	—				7		C_6H_6	Benzene		t.
2750 V	—	—	—		1		CO	Kaplan	F.	H.
*2747·6 R		—			9		NO	β	D.	N.
2747 R	5						CH_2O	Formaldehyde		
2745·3 R	9				8		SiS		S.	
*2744·5 R	7						Bi_2			
2744·0 R		6			6		SO			
2740 V					?		N_2	Kaplan 2		
2739·1 R	—				10		C_6H_6	Benzene		t.
2736·5 R	—				8		C_6H_6	Benzene	S.	t.
*2731·6 R	10						Bi_2			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
2722·3 R	—	—	—			6	CO^+	1st Negative		He.
*2722·2 V	*3*	*9*	*9*		9		NO	γ	DCD.	
2722·2 V					10		BCl			
*2720·7 R	8						Bi_2			
2720·0 V					10		BCl			hf.
2719·5 R					7		AsN		CD.	
2716·9 R				9			SnO	Loomis & Watson		
2716·0 R		5					CHO ?	Ethylene flame		
2714·2 R					8		BCl		S.	hf.
2713·8 R			10				BO	β		N.
2713·6 R	?				?		TlF		S.	
2711·3 V	—	—	—		3		CO	3A.	Fd.	
*2710·3 R	6						Bi_2			
2706·8 V		*2*	3		3		PO	γ	CD.	
2705·3 R	—	—	—			8	O_2^+	2nd Negative	D.	He.
2699·1 R		*4*			4		SO			
2697·4 R					5		NS	β		
*2693·7 R		7	*9*		9		SiO			
*2693·2 R		*8*	8		8		CS		CD.	
2692·4 V		*3*	4		4		PO	γ	CD.	
2690·8 V		*3*	4		4		PO	γ	CD.	
2689·3 V			5				MgF		S.	
*2685·7 V					7		AlCl			
2683·3 R					4		NS	β		
*2683·1 V					7		AlCl			
2680·0 R					4		NS	β		
*2680·0 V	*0*	*3*	*5*		5		NO	γ	DCD.	
2678·6 R					9		C_6H_6	Benzene		t.
*2677·0 R		*6*	6		6		CS		CD.	
2676·7 V		*3*	4		4		PO	γ	CD.	
2675·3 R			8				BO	β		N.
2672·4 R	—	—	—			7	CO^+	1st Negative		He.
*2672·2 R		—			7		NO	β	D.	N.
*2669·0 R		8	*9*		9		SiO			
*2667·4 R	1				10		C_6H_6	Benzene	S.	t.
*2665·3 V	—	—	—		8		CO	5B	F.	
2664·8 R		*5*			5		SO			
2662·9 V		*2*	3		3		PO	γ	CD.	
*2662·6 R		*10*	9		10		CS		CD.	
2660·5 V	—	—	—		5		N_2	4th Positive	F.	c.
2659·8 R					8		BCl		S.	hf.
2658·8 R		4					CHO ?	Ethylene flame		
*2649·7 V					5		AlCl			
*2647·5 V					7		AlCl			
*2644·8 R		4	*4*		4		SiO			
2638·8 R	—	—	—			8	CO^+	1st Negative		He.
2636·3 V		*6*	7		7		PO	γ	CD. S.	
2635 V					?		N_2	Kaplan 2		
2632·7 R	—	—	—			7	O_2^+	2nd Negative	D.	He.
2630 V	—	—	—		2		CO	Kaplan		

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
*2623·5 R					6		AlCl			
2623·4 V		6	7		7		PO	γ	CD.	
2622·2 R		2			3		SO			
2620·5 V		7	8		8		PO		CD.	
*2620·5 R		—			6		NO	β	D.	N.
*2620·0 R					5		AlCl			
*2617·0 R					5		AlCl			
2614·6 R					4		NS	β		
*2614·4 R					10		AlCl			
2613·6 R					8		C_6H_6	Benzene		t.
*2610·2 R					6		AlCl			
*2608·5 R		2		3	3		OH		DCD. wv.	
2608·0 V		6	7		7		PO	γ	CD.	
2607·2 R	—	—	—			8	CO^+	1st Negative		He.
*2605·9 R		9	9		10		CS		CD.	
2605·0 R					9		PN		CD. S.	
2603·8 R					10		N_2	Vegard-Kaplan		
*2602·6 R	2				9		C_6H_6	Benzene	S.	t.
*2602·1 R		—			6		NO	β	D.	N.
2597·1 R					6		NS	β		
2596·9 V	—	—	—		4		CO	3A.	Fd.	
*2595·7 V	5	10	10		10		NO	γ	CD.	
2595·5 V	?						SnF		CD.	
2591 M	5	—	—				O_2	Herzberg	T.	
*2589·6 R		6	6		6		CS		CD.	
2589·0 R		2			2		SO			
*2589·0 R	9						C_6H_6	Benzene	S.	
2588·0 R			8				BO	β		N.
*2587·5 V	5	10	10		10		NO	γ	CD.	
*2587·1 R		8	5		5		SiO			
2586·5 V					?		N_2	Van der Ziel		
2584·8 R					5		NS	β		
2581·0 R	—	—	—			9	O_2^+	2nd Negative	D.	He.
2577·7 R	—	—	—			10	CO^+	1st Negative		He.
*2575·6 R		10	10		10		CS		CD.	
2575·3 R					8		CO	Cameron	F.	He. r.
2575 R					6		CO ?	Kaplan		
2570·9 V	9	9	9		9		AsO		CD. S.	
*2563·8 R		8	5		5		SiO		S.	
*2558·6 V	1	3	5		5		NO	γ	DCD.	
*2557·3 V	—	—				1	NH			
2555·0 V		9	10		10		PO	γ	CD.S.	
2553 M	7	—	—				O_2	Herzberg	T.	
2553·3 R					6		CO	Cameron	F.	He. r.
*2551·8 R		—			5		NO	β	D.	N.
2551·4 R			9				BO	β		N.
2550·7 V	—	—	—		8		N_2	4th Positive	F.	c.
2550·3 R	—	—	—			7	CO^+	1st Negative		He.
2548·6 R		1			2		SO			
2545·5 R	—	—	—			8	O_2^+	2nd Negative		He.

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
2543·9 V		6	7		7		PO	γ	CD.	
2540·4 V		6	10		10		PO	γ	CD.	
2539·2 V					7		SiF	γ	D.	
*2538·5 R		4	5		6		CS		CD.	
2536 V					?		N_2	Kaplan 2		
2535·0 V					10		HgCl			hf.
2532·8 R	—	—	—			7	O_2^+	2nd Negative		He.
*2530·2 V	—	—				3	NH		L.	
2529·4 V		6	7		7		PO	γ	CD.	
*2528·6 R	10						C_6H_6	Benzene	S.	
*2523·2 R		6	6		7		CS		CD.	
2518·5 R					8		NS	β		
2518·2 R					10		PN		CD. S.	
2518 M	9	—	—				O_2	Herzberg	T.	
2518 V	—	—	—		2		CO	Kaplan	F.	H.
2516·5 V					10		HgCl			hf.
2510·9 R					6		CO	Cameron	F.	He. r.
*2509·9 R		3	4		4		SiO			
2509·8 R					6		N_2	Vegard-Kaplan		
2506·7 R					8		NS	β		
2504·7 V	10	8	8		8		AsO		CD. S.	
2504·6 R	—	—	—			10	CO^+	1st Negative		He.
2496·9 V					?		N_2	Van der Ziel		
2495·4 V					10		HgCl			hf.
*2493·7 R		2	4		6		CS		CD.	
2491·4 R	6						NO_2			
2491 R					4		CO	Cameron	F.	He. r.
2490·6 R	10				10		GaCl			hf.
2489·9 V	—	—	—		5		CO	3A.	Fd.	
2489 M	10	—	—				O_2	Herzberg	T.	
2488·3 R	—	—	—			6	O_2^+	2nd Negative	D.	He.
*2487·8 R		—			7		NO	β	D.	N.
*2486·8 R		10	7		6		SiO		S.	
*2478·7 V	7	10	10		10		NO	γ	CD.	
2477·9 V		9	10		10		PO	γ	CD. S.	
*2477·0 R		2	3		4		CS		CD.	
2476·1 R					10		Hg_2^+			hf.
2474·2 R	—	—	—			10	CO^+	1st Negative		He.
*2471·1 V	7	10	10		10		NO	γ	CD.	
*2471·0 R	9						C_6H_6	Benzene	S.	
2468·3 V		5	6		6		PO	γ	CD.	
2667·8 V					6		SiCl			
2465 M	9	—	—				O_2	Herzberg	T.	
2464·2 V		9	10		10		PO	γ	CD.	
2463·2 R					10		CO	4th Positive		
2461·6 R					9		N_2	Vegard-Kaplan		
2460·7 R					7		NS	β		
*2460·2 R		3	4		5		CS		CD.	
2459·3 R	5						NO_2			
*2459·0 R		4	3		3		SiO			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
					7		SiCl			
		5	6		6		PO	γ	CD.	
					5		NS	γ	CD.	
[illegible] R					6		CO	Cameron	F.	He. r.
·1 R					8		PN		CD. S.	
2448·7 R					6		NS	β		
2448·0 V	—	—	—		10		N_2	4th Positive	F.	c.
2445·8 R	—	—	—			10	CO^+	1st Negative		He.
*2444·8 R		*2*	2		3		CS		CD.	
2440 M	*7*	—	—				O_2	Herzberg		
2439·7 V					4		NS	γ	CD.	
2438·5 V	8	*3*	4		*4*		AsO		CD. S.	
2437·1 R			10				BO	β		N.
*2436·3 R			*3*		3		SiO			
2433·9 R					9		CO	4th Positive		
2429·2 V					10		MgH			
*2427·8 R		—			7		NO	β	D.	N.
2424·1 V					10		MgH			
2419·4 R	—	—	—			8	CO^+	1st Negative		He.
2419 R	10						NO_2			
*2415·9 R	5						C_6H_6	Benzene	S.	
*2413·8 R		8	*7*		7		SiO		S.	
2411·7 V					?		N_2	Van der Ziel		
2409·2 R					6		CO	Cameron	F.	He. r.
2406·0 R					4		NS	β		
2398·5 R			10				BO	β		N.
2396·3 V		*7*	8		8		PO	γ	CD. S.	
2394·4 R					4		NS	β		
2392·6 R	—	—	—			3	O_2^+	2nd Negative	D.	He.
2389·7 V	—	—	—		5		CO	3A.	Fd.	
2388·8 R					6		CO	Cameron	F.	He. r.
*2387·9 R		3	*5*		5		SiO			
2387·9 V		*6*	7		7		PO	γ	CD.	
2383·6 V					10		NS	γ	CD.	
2383·5 V		*7*	8		8		PO	γ	CD.	
2381 V					?		N_2	Kaplan 1		
2377·5 R					7		N_2	Vegard-Kaplan		
2375·2 V		*6*	7		7		PO	γ	CD.	
2371·1 V					10		NS	γ	CD.	
*2370·2 V	*9*	*9*	*9*		9		NO	γ	DCD.	
*2365·7 R		1	*6*		6		SiO			
*2364·5 R		4					SiO			
2364·5 R			8				BO	β		N.
*2363·5 R	3						C_6H_6	Benzene	S.	
2352·5 R	—	—	—			6	CO^+	1st Negative		He.
2351·4 V	—	—	—		6		N_2	4th Positive	F.	c.
*2344·3 R		4	*5*		5		SiO		S.	
*2342·4 R		4	*1*		1		SiO			
2342 M	*10*				10		Hg_2			f.
2333·8 R	*9*						As_2			

	Ab.	F.	A(a).	A(r).	D+.	D−.		System.	App.	Occ.
2332·8 R					4		N_2	Vegard-Kaplan		
2331·3 R			7				BO	β		N.
2330·4 R			6				BO	β		N.
*2326·6 R		—			3		NO	β	D.	N.
2325 M	—				10		C_2	Mulliken		hf.
2325·2 R	—	—	—			9	CO^+	1st Negative		He.
2320·6 V		*2*	3		3		PO	γ	CD. S.	
2319·7 R	*10*						As_2			
*2317·7 V	*1*	—			2		NO	δ	DCD.	
2317·3 V	8		10				AlF			
2317·2 V					10		NS	γ	CD.	
2313·7 V		*3*	4		4		PO	γ	CD.	
2306·9 V			4		4		PO	γ	CD.	
2306·0 R	*10*						As_2			
2305·2 V					8		NS	γ	CD.	
2301·7 V		*3*	4		4		PO	γ	CD.	
2301 V					?		N_2	Kaplan 1		
2299·6 R	—	—	—			10	CO^+	1st Negative		He.
2298·9 R		2	*6*		6		SiO		S.	
2295·9 V	—	—	—		4		CO	3A.	Fd.	
2292·7 R	*10*						As_2			
2279·6 R	*10*						As_2			
2278·3 R	10		10				AlF			
2276·7 V			*4*				MgF		S.	
2275·3 M	10						AlF			
*2269·4 V	*7*	*5*	*5*		5		NO	γ	DCD.	
2268·6 R	—	—	—			3	CO^+	1st Negative		He.
2266·7 R	*9*						As_2			
2266·3 V	?						SnF		CD.	
2264·8 R			6				BO	β		N.
2263·9 R	—	—				10	HgH^+			
2261·7 R					9		CO	4th Positive		
2260·8 V	—	—	—		2		N_2	4th Positive	F.	c.
2258·4 V					5		SiCl		D.	
2257·7 R					1		CO	Cameron	F.	He. r.
*2255·9 R		1	*4*		5		SiO		S.	
*2255·8 O				1			AlH			
2244·9 R	8						Sb_2			
*2244·3 V	*3*	*1*	*2*		2		NO	γ	DCD.	
2239·2 R	2						CuH			
2238·3 R					9		CO	4th Positive		
*2236·3 R		1	*2*		2		SiO			
2231·5 V					4		SiCl			
*2228·6 R				1			AlH			
*2226·8 V	*2*	—			3		NO	δ	DCD.	
2225 V					?		N_2	Kaplan 1		
2222·8 R	10						Sb_2			
2221·5 R					10		CO	4th Positive		
*2221·3 V	*2*	*0*	*2*		2		NO	γ	DCD.	
2217·5 V					?		O_2	Hopfield		c. He.

	Ab.	F.	A(a).	A(r.)	D+.	D−.		System.	App.	Occ.
*2215·4 R		0	*2*		2		SiO			
2214·5 R	—	—	—			5	CO^+	1st Negative		He.
2209·4 R	8						Sb_2			
2196·8 R					10		CO	4th Positive		
2189·8 R	—	—	—			10	CO^+	1st Negative		He.
2188·2 R	9						C_2N_2			
2173·0 R					9		CO	4th Positive		
2170·0 V					?		O_2	Hopfield		c. He.
2163·7 R	6						NH_3		D.	
2157·1 V	?						SnF		CD.	
*2156 V	*5*	*1*	*3*		3		NO	γ	DCD.	
2153 V					?		N_2	Kaplan 1		
2143·9 R					*6*		N_2	Lyman		
*2141·3 V	*3*	—			4		NO	δ	DCD.	
2137·8 R	—	—	—			6	CO^+	1st Negative		He.
2125·9 R					*9*		N_2	Lyman		
2123·9 R	6						NH_3		D.	
2123·1 V					?		O_2	Hopfield		c. He.
2113·1 R					9		CO	4th Positive		
2112·4 R	—	—	—			8	CO^+	1st Negative		He.
2112·1 V					?		N_2	Kaplan 1		
2093·1 R	10						C_2N_2			
2089·9 R					10		CO	4th Positive		
2084·1 R	7						NH_3		D.	
2076·6 V					?		O_2	Hopfield		c. He.
2074·4 R					10		ZnCl			hf.
2067·6 R					10		CO	4th Positive		
*2062 V	*3*	—			3		NO	δ	DCD.	
2059·6 R	6						CO	Cameron	F.	He. r.
2046·3 R					10		CO	4th Positive		
2045·7 R	9						NH_3		D.	
2041·2 R					*10*		N_2	Lyman		
2030·8 V					?		O_2	Hopfield		c. He.
2025·8 R					9		CO	4th Positive		
2023·5 R					*7*		N_2	Lyman		
2010·9 R	10						NH_3			
2007·0 R	10						C_2N_2			
2006·0 R					*4*		N_2	Lyman		

INDIVIDUAL BAND SYSTEMS

In this section detailed lists of bands are given for each system separately and are arranged in alphabetical order of the chemical symbols of the molecules concerned. The elements in the molecule are taken in the order which appears most frequently in the chemical literature, thus usually the more metallic element appears first as in CaCl, AgO, MgH, while OH is used in preference to HO, but HCl rather than ClH.

For each molecule a few general introductory remarks are made at the beginning if the spectrum is particularly important or complex, and then the various band systems are dealt with separately, the more important systems being given first. The treatment for the systems varies somewhat according to the particular case, but the spectrum is usually dealt with under some or all of the following headings :—

Occurrence. Mention is made of various sources from which the system has been obtained. This serves to give a general idea of the conditions which are most favourable to the production of the system, but does not of course imply that the bands cannot be obtained with some intensity in other sources. Arc sources usually refer to low voltage (100–200 v.) arcs running in air at atmospheric pressure. Where a band system is of very frequent occurrence as an impurity this is indicated.

Appearance. The direction in which the bands are shaded is recorded, *e.g.*, degraded to shorter wave-lengths, indicating that the bands have sharp heads on the red side and are shaded to the violet. A brief description of the system is given calling attention to any outstanding characteristics which help to identify it, *e.g.*, outstanding sequences, double-headed bands, line-like heads which might be mistaken for atomic lines.

Transition. The type of electronic transition is stated as this gives additional information as to the appearance of the system, especially when seen under high dispersion. Where the lower electronic level is known to be the normal or ground state this is also stated as such systems are likely to occur in absorption. A detailed account of the rotational structure and appearance of the various electronic transitions is beyond the scope of this work, but the following brief indications may be useful ; the appearance depends greatly on the relative values of the molecular constants in the two electronic states and upon the dispersion with which the band is studied, and so certain bands may differ considerably from the following very brief generalisations :—

$^1\Sigma \rightarrow {}^1\Sigma$. Single P and R branches. Single-headed.

$^1\Sigma \rightarrow {}^1\Pi$, $^1\Pi \rightarrow {}^1\Sigma$. Single P, Q and R branches. Usually double-headed.

$^2\Sigma \rightarrow {}^2\Sigma$. Double P and R branches, very weak satellite branches. Usually close double-headed.

$^2\Pi \rightarrow {}^2\Pi$, $^2\Delta \rightarrow {}^2\Delta$. Two P and two R branches and short weak Q branches and satellite branches. Molecules with small spin (multiplet) splitting (Hund's case *b*) show double-headed bands ; molecules with large spin splitting (Hund's case *a*) show two separate single-headed bands.

$^2\Sigma \rightarrow {}^2\Pi$, $^2\Pi \rightarrow {}^2\Sigma$, $^2\Pi \rightarrow {}^2\Delta$, $^2\Delta \rightarrow {}^2\Pi$. Double P, Q and R branches and weak satellite branches. Often double double-headed. In Hund's case *b* the doubling is small and the satellite branches are very weak. In Hund's case *a* the doubling is large so that the appearance is of two separate double-

headed bands, and the satellite branches are stronger forming definite heads in front of the main heads.

$^3\Sigma \rightarrow {^3\Sigma}$. Triple P and R branches, weak Q and satellite branches. Close triple-headed.

References. References are given to those papers which are most useful for the purpose of identification. Those which contain useful photographs are indicated by a dagger following the date, *e.g.*, (1939)†. Often an early paper gives a far better general description of a system than later papers.

The following abbreviations are used :—

P.R. *Physical Review.*
P.R.S. *Proceedings of the Royal Society, Series A.*
Z.P. *Zeitschrift für Physik.*

In the lists of heads which follow, the wave-lengths are given to the nearest 0·1 A., followed wherever possible by estimates of intensities and vibrational quantum numbers. In many cases the intensity estimates are made by the authors either from their own plates or from published photographs.

AgBr

Occurrence. In absorption and fluorescence.
Appearance. Single-headed bands degraded to the red.
Transition. Probably $^1\Sigma \rightarrow {^1\Sigma}$ ground state.
References. J. Franck and H. Kuhn, *Z.P.*, **44,** 607. (1927).
B. A. Brice, *P.R.*, **38,** 658. (1931)†.

The bands observed in absorption by Brice are numerous and extend from 3500 A. to 3165 A. Those observed by Franck and Kuhn are in the region λλ3393–3182. No intensities are given, but the following bands are probably among those most easily observed :—

λ	v′, v″	λ	v′, v″
3310·8	1, 5	3250·8	0, 2
3302·8	0, 4	3232·7	1, 2
3284·2	1, 4	3225·2	0, 1
3276·7	0, 3	3199·5	0, 0
3258·3	1, 3	3182·1	1, 0

AgCl

STRONG SYSTEM, λλ3379–3114

Occurrence. In discharge tubes (including high-frequency discharge) containing silver chloride, in fluorescence and in absorption.
Appearance. Degraded to the red. Marked sequences.
Reference. B. A. Brice, *P.R.*, **35,** 960. (1930)†.
Strong bands as given by Brice :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3251·4	4	2, 4	3200·8	9	0, 1	3157·5	7	3, 2
3243·2	5	1, 3	3181·9	4	2, 2	3147·9	8	2, 1
3236·0	3	0, 2	3173·3	5	1, 1	3139·7	9	1, 0
3216·3	8	2, 3	3166·2	10	0, 0	3124·2	3	2, 1
3208·0	9	1, 2						

AgCl (*contd.*)

WEAKER SYSTEMS

Occurrence. In absorption.

Appearance. Degraded to red.

Reference. F. A. Jenkins and G. D. Rochester, *P.R.*, **52, 1141.** (1937).

λλ2400–2200. No intensities are given ; the following may be the strong bands :—

λ	v′, v″	λ	v′, v″	λ	v′, v″
2390·3	0, 5	2300·6	1, 1	2238·4	4, 0
2365·9	0, 4	2285·3	2, 1	2224·2	5, 0
2352·9	0, 3	2270·4	3, 1	2210·2	6, 0
2318·7	1, 2	2252·9	3, 0	2196·5	7, 0
2303·2	2, 2				

λλ2200–2100. No intensities given. The following may be the strong bands :—

λ	v′, v″
2150·3	0, 8
2135·4	0, 7
2120·7	0, 6

OTHER BANDS

Reference. P. Mesnage, *C.R. Acad. Sci. Paris*, **200**, 2072. (1935).

Mesnage has observed the following bands, degraded to the red, in a high-frequency discharge through a heated quartz tube containing silver chloride ; " the origin is not actually known." λλ4608, 4560, 4509, 4427, 4390, 4199 ; λλ2822, 2806, 2802, 2791, 2778, 2775 and 2764.

AgH

References. E. Bengtsson and E. Olsson, *Z.P.*, **72,** 163. (1931).
E. Bengtsson, *Nova. Acta Reg. Soc. Sci. Uppsala* (IV), **8,** No. 4. (1932).

3330 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$

Occurs in discharges where silver vapour is mixed with hydrogen. The bands given below were obtained by Bengtsson and Olsson in the spectrum of an arc in hydrogen between electrodes of silver aluminium alloy.

Bands with single R and P branches degraded to the red.

Heads

λ	v′, v″	λ	v′, v″
3179	1, 0	3781	2, 4
3220	2, 1	3833	3, 5
3275	3, 2	3905	4, 6
3330	0, 0	3990	5, 7
3357	1, 1	4039	3, 6
3396	2, 2	4108	4, 7
3451	3, 3	4190	5, 8
3516	0, 1	4273	6, 9
3546	1, 2	4328	4, 8
3583	2, 3	4397	5, 9
3637	3, 4	4472	6, 10
3710	4, 5	4536	7, 11
3740	1, 3	4669	6, 11

Mention is made of other bands from 2700 A. to the further ultra-violet.

AgI

Occurrence. In absorption. Some of the bands (mostly those with v′ = 0) have also been observed in fluorescence by Franck and Kuhn.

References. J. Franck and H. Kuhn, *Z.P.*, **43,** 164. (1927).
B. A. Brice, *P.R.*, **38,** 658. (1931)†.

Bands λλ3556–3168 degraded to the red. The shorter wave-length bands have been observed by Franck and Kuhn and the longer wave-length bands of the system by Brice. The following are probably the strong bands; no intensities have been recorded. The values taken from Brice are for the isotope $Ag^{109}I$.

λ	v′, v″	λ	v′, v″	λ	v′, v″
3436·9	3, 12	3358·1	2, 8	3252·7	0, 2
3425·8	2, 11	3348·0	1, 7	3231·3	0, 1
3414·3	3, 11	3325·9	1, 6	3218·9	1, 1
3403·1	2, 10	3316·8	0, 5	3210·0	0, 0
3393·0	1, 9	3294·7	0, 4	3198·0	1, 0
3380·4	2, 9	3274·5	0, 3	3186·7	2, 0
3370·5	1, 8				

AgO

Occurrence. Arc between silver poles in an atmosphere of oxygen.

Reference. F. W. Loomis and T. F. Watson, *P.R.*, **48,** 280. (1935).

There are two strong band systems attributed to AgO, in the blue and ultra-violet, and some faint bands have been observed (but not measured) in the red.

Blue System

Appearance. Degraded to red.

Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.

The following are presumably the R_1 and R_2 heads. A few weak bands are omitted. Intensities on a scale of 5.

λ	I	v′, v″	λ	I	v′, v″
4614·6	1	0, 5	4337·4	2	0, 2
4577·9	1		4304·7	2	
4519·7	2	0, 4	4294·0	3	1, 2
4484·6	2		4262·8	3	
4427·4	1	0, 3	4207·6	4	1, 1
4393·8	3		4177·5	4	
4382·4	2	1, 3	4123·6	5	1, 0
4349·8	0		4094·5	5	

Ultra-violet System

Appearance. Degraded to shorter wave-lengths. Marked sequences.

Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

P heads of strong bands. Intensities on a scale of 5.

λ	I	v′, v″	λ	I	v′, v″
3620·7	2	0, 1	3493·5	2	1, 0
3614·9	2	1, 2	3490·2	3	2, 1
3609·3	2	2, 3	3487·8	3	3, 2
3558·4	4	0, 0	3484·2	1	5, 4
3553·5	5	1, 1	3481·4	1	—

AlBr

Occurrence. High-frequency discharge through aluminium tribromide vapour.
Appearance. Degraded to the red. Close double-headed bands, separation between the R and Q heads being about 0·2 A.
Transition. Probably $^1\Pi \rightarrow {}^1\Sigma$, ground state.
Reference. H. G. Howell, *P.R.S.*, **148**, 696. (1935)†.

The following are the R heads of the strong bands :—

λ	I	v′, v″	λ	I	v′, v″
2855·3	7	1, 3	2804·9	8	2, 2
2848·0	6	0, 2	2796·3	9	1, 1
2834·1	8	2, 3	2788·8	10	0, 0
2825·6	8	1, 2	2775·8	8	2, 1
2818·3	9	0, 1	2767·2	9	1, 0

AlCl

Occurrence. Uncondensed discharge through $AlCl_3$ vapour. This system is frequently observed as an impurity in discharge tubes with aluminium electrodes.
Appearance. As may be seen from Plate 1, this system is of rather complex structure. The 2, 0, 1, 0 and 0, 0 sequences are degraded to the red, and the bands are close double-headed, with additional weak heads due to the less abundant isotope of chlorine. Some of the bands of the 0, 2 and 0, 1 sequences are degraded to shorter wave-lengths. The heads of the 0, 0 band at 2610 and 2614 A. are usually outstanding if the system is only weakly present, *e.g.*, as an impurity.
Transition. $^1\Pi \rightarrow {}^1\Sigma$, probably ground state.
References. B. N. Bhaduri and A. Fowler, *P.R.S.*, **145**, 321. (1934)†.
W. Holst, *Z.P.*, **93**, 55. (1934–35).

The following measurements of the outstanding heads are from Bhaduri and Fowler. Intensities are on a scale of 8. Weaker isotope heads are omitted, and for the close double-headed bands degraded to the red, only the R heads are given, the Q heads being usually less than 1 A to the red. The letters R or V after the wave-length indicate the direction of degradation of the band, while the nature of the head (R or Q) is indicated before the vibrational quantum numbers.

λ	I	v′, v″	λ	I	v′, v″	
2708·9 R	2	R 7, 9	2623·5 R	5	Q 3, 3	
2702·3 R	3	R 6, 8	2622·4 R	4	R 3, 3	
2696·4 R	3	R 5, 7	2620·0 R	4	Q 2, 2	
2692·8 R	5	Q 4, 6	2618·2 R	3	R 2, 2	
2685·7 V	6	Q 2, 4	2617·0 R	4	Q 1, 1	
2683·1 V	6	Q 1, 3	2614·4 R	8	Q 0, 0	R 1, 1
2681·1 V	4	Q 0, 2	2610·2 R	6	R 0, 0	
2649·7 V	4	Q 1, 2	2606·7 R	2	R 6, 5	
2647·5 V	6	Q 0, 1	2600·7 R	3	R 5, 4	
2644·9 R	2	R 7, 7	2595·4 R	2	R 4, 3	
2638·1 R	3	R 6, 6	2590·8 R	2	R 3, 2	
2632·8 R	3	Q 5, 5	2586·7 R	2	R 2, 1	
2632·2 R	3	R 5, 5	2564·3 R	1	R 4, 2	
2627·8 R	4	Q 4, 4	2559·6 R	1	R 3, 1	
2627·0 R	3	R 4, 4	2555·5 R	1	R 2, 0	

AlF

Near Ultra-violet System

Occurrence. Discharge through heated tube containing AlF_3.

Appearance. Degraded to the red ; marked sequences.

Reference. T. Yuasa, *Sci. Rep. Tokyo Bunrika Daigaku*, 3A, 239. (1938)†.

Heads of strongest sequences.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4039·8	3	0, 7	3732·5	3	0, 4	3465·4	2	0, 1
3931·7	4	0, 6	3640·4	3	0, 3	3383·9	2	0, 0
3830·2	4	0, 5	3550·7	2	0, 2	3309·2	2	1, 0
						3244·2	2	2, 0

The published analysis, as reproduced above, appears far from convincing, as the strongest bands fall on a very open Franck-Condon parabola which would not be expected from an analysis using nearly equal values of ω' and ω''. As far as can be seen from the published photographs, many of the strongest heads are unassigned.

Far Ultra-violet System

Occurrence. In absorption.

Reference. G. D. Rochester, *P.R.*, **56**, 305. (1939)†.

The system is very symmetrical, being hardly degraded in either direction. The (0, 0) band shows a line-like Q branch at 2278·3 A. and headless P and R branches on each side. The (1, 0) sequence shows a head at 2234·4 A. degraded tc the red. The (0, 1) sequence shows a head at 2317·3 A. degraded to shorter wave-lengths.

AlH

Some eight band systems are attributed to AlH. Under conditions of mild excitation the λ4241 system is the strongest. The prominent heads at 4241A and 4259A are frequently observed in discharge tubes with aluminium electrodes.

References. E. Bengtsson and R. Rydberg, *Z.P.*, **59**, 540. (1930).
J. W. I. Holst, *Dissertation, Stockholm.* (1935).
W. Holst and E. Hulthén, *Z.P.*, **90**, 712. (1934)†.
E. Olsson, *Z.P.*, **104**, 402. (1936).

4241 A, System, B $^1\Pi \rightarrow$ A $^1\Sigma$, Ground State

Double-headed bands of open structure degraded to the red. Occurs readily in emission in discharges where aluminium vapour and hydrogen are present together. May also be obtained in absorption.

	Origins	Heads	
v′, v″	λ	R.	Q.
1, 2	4680·5	4670·9	4680·7
0, 1	4576·3	4546·5	4576·4
1, 1	4360·1	4353·1	4360·5
0, 0	4259·3	4241·0	4259·5
1, 0	4071·6	4066·3	4072·6

Reference. E. Bengtsson, *Z.P.*, **51**, 889. (1928).

AlH (*contd.*)

2229 A. SYSTEM, C $^1\Sigma \rightarrow$ A $^1\Sigma$, GROUND STATE

Weak bands with P and R branches slightly degraded towards the red.

	Origins	Head
v′, v″	λ	R.
0, 0	2241·6	2228·6
1, 1	2255·8	

2033 A. SYSTEM, D $^1\Sigma \rightarrow$ A $^1\Sigma$, GROUND STATE

Weak band with P and R branches, neither forming definite head. The P branch stretches to about 2033 A.

	Origin
v′, v″	λ
0, 0	2028·2

4752 A. SYSTEM, C $^1\Sigma \rightarrow$ B $^1\Pi$

Bands show P, Q and R branches degraded to the violet.

Head
Q
4731·8

4980 A. SYSTEM, E $^1\Sigma \rightarrow$ B $^1\Pi$

Obtained in an arc between aluminium and carbon electrodes in hydrogen. Band shows P, Q and R branches degraded to the red.

	Origin	Heads	
		R.	Q.
0, 0	4988	4886	4929

3380 A. SYSTEM, F $^1\Pi \rightarrow$ B $^1\Pi$

Bands degraded to the red, each with two P and two R branches.

	Origin	Heads	
0, 0	3390	3379·4	3384·8

Reference. W. Holst, *Z.P.*, **86**, 337. (1933).

3800 A. SYSTEM, *b* $^3\Sigma \rightarrow$ *a* $^3\Pi$

Triplet bands with three P and three R branches symmetrically arranged about piled up Q branches ; similar to the 3360 A. band of NH. The (1, 1) band shows a weaker Q maximum on the long wave side of the (0, 0).

	Origin
0,0	3812·6

Reference. W. Holst, *Z.P.*, **89**, 47. (1934).

2700 A. SYSTEM. Brief mention of a band about 2700 A.

AlH$^+$

References. W. Holst, *Z.P.*, **89**, 40. (1934)†.
G. M. Almy and M. C. Watson, *P.R.*, **45**, 871. (1934)†.

AlH+ (*contd.*)

3602 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$

Bands degraded to the violet. Observed in arc between Al electrodes in hydrogen at reduced pressures, in discharge through a mixture of $AlCl_3$ vapour and hydrogen, and in hollow aluminium cathode containing hydrogen and helium.

Heads

0, 0 Band	1, 1 Band
3632·3 P_1	3600·5 P_2
3630·2 P_2	3593·0 Q_1
3611·9 Q_1	3583·0 Q_2
3602·4 Q_2	

AlI

Occurrence. In discharge tubes of various types containing aluminium iodide, and in absorption.
Appearance. Two systems in the blue degraded to the violet, and a single progression of diffuse bands in the ultra-violet.
References. E. Miescher, *Helv. Phys. Acta.*, **8**, 279. (1935)†.
E. Miescher, *Helv. Phys. Acta.*, **9**, 693. (1936)†.

SYSTEM A, A $^3\Pi \rightarrow {}^1\Sigma$, GROUND STATE

Strongest bands :

λ	I	v′, v″
4631·4	7	0, 1
4565·0	10	0, 0
4561·1	8	1, 1
4496·6	8	1, 0
4431·0	3	2, 0

SYSTEM B, B $^3\Pi \rightarrow {}^1\Sigma$, GROUND STATE

Strongest bands :

λ	I	v′, v″
4589·2	2	0, 1
4524·0	7	0, 0
4520·9	4	1, 1

ULTRA-VIOLET SYSTEM, $^1\Pi \rightarrow {}^1\Sigma$, GROUND STATE

λ	v′, v″	λ	v′, v″
3426	0, 5	3295	0, 2
3382	0, 4	3244	0, 1
3339	0, 3	3175	0, 0

OTHER BANDS

Miescher also records numerous bands, degraded to the red, in the blue and violet.

AlO

Occurrence. Aluminium arc in air and Al salts in carbon arc.
Appearance. Degraded to red. Marked sequences of single-headed bands. See Plate I.
Transition. B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.
References. W. C. Pomeroy, *P.R.*, **29**, 59. (1927)†.
G. Eriksson and E. Hulthén, *Z.P.*, **34**, 775. (1929).

AlO (*contd.*)

The following heads are taken from unpublished spectrograms by W. Jevons. Weak bands are omitted.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5424·3	2	5, 7	5102·1	5	1, 2	4648·2	8	1, 0
5410·5	3	4, 6	5079·3	4	0, 1	4557·5	3	6, 4
5394·8	3	3, 5	4888·4	6	2, 2	4537·6	4	5, 3
5377·4	2	2, 4	4866·1	9	1, 1	4516·3	4	4, 2
5358·1	2	1, 3	4842·1	10	0, 0	4494·0	3	3, 1
5336·9	1	0, 2	4735·5	6	5, 4	4470·5	2	2, 0
5160·8	3	4, 5	4715·5	6	4, 3	4393·8	1	7, 4
5142·9	4	3, 4	4694·6	7	3, 2	4373·7	1	6, 3
5123·3	5	2, 3	4672·0	8	2, 1			

We have also observed a system of bands in the ultra-violet which are probably due to AlO. These occur in a high-tension arc between aluminium electrodes in a flame and weakly in an arc in air. The following are the two outstanding heads degraded to the red :—

3020·5 A., 3028 A.

As_2

Occurrence. In discharge tube (with hydrogen as a carrier of the discharge) containing arsenic vapour, in absorption and in fluorescence.

Appearance. A very extensive system of bands degraded to the red.

Transition. The bands have been analysed by Almy and Kinzer into two strong and two weak systems, all having the same final level which is probably $^1\Sigma$. The intensity distribution of all these systems is far from smooth.

References. G. E. Gibson and A. MacFarlane, *P.R.*, **46**, 1059. (1934)†.
G. M. Almy and G. D. Kinzer, *P.R.*, **47**, 721. (1935).
G. D. Kinzer and G. M. Almy, *P.R.*, **52**, 814. (1937)†.

The strongest bands as listed by Almy and Kinzer are given below. The letter A in the intensity column indicates that the band is observed strongly in absorption.

System A, λλ5555–2240.

λ	I	v′, v″		λ	I	v′, v″	λ	I	v′, v″
3715·3	4	14, 45		2922·3	5	5, 16	2506·9	6	5, 4
3543·0	4	14, 41		2889·1	5	2, 15	2490·6	4	6, 4
3501·6	4	14, 40		2856·4	5	2, 14	2480·7	5	5, 3
3368·7	4	9, 33		2846·4	4	4, 15	2464·7	5	6, 3
3329·0	4	9, 32		2803·3	4	6, 15	2455·0	4	5, 2
3318·0	5	8, 31		2753·7	4	7, 14	2449·9	6	7, 3
3240·5	4	8, 29		2712·3	4	6, 12	2439·4	5	6, 2
3140·5	4	6, 25	9, 27	2683·1	4	6, 11	2424·9	5	7, 2
3104·5	5	6, 24	9, 26	2658·9	4	9, 12	2410·6	4	8, 2
3093·5	5	5, 23		2644·0	4	5, 9	2357·1	A	10, 1
3069·0	5	9, 25		2637·0	4	7, 10	2333·8	A	10, 0
3058·0	4	8, 24		2592·7	4	8, 9	2319·7	A	11, 0
3011·0	4	7, 22		2587·9	4	5, 7	2306·0	A	12, 0
2965·0	4	6, 20		2578·9	4	4, 6	2292·7	A	13, 0
2956·0	4	2, 17		2570·4	5	6, 7	2279·6	A	14, 0
2931·5	4	6, 19		2551·6	5	4, 5	2266·7	A	15, 0
2922·9	5	8, 20		2533·4	4	5, 5	2254·0	A	16, 0

As_2 *(contd.)*

SYSTEM B, λλ5530–2350

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4376·0	4	2, 50	3141·8	5	1, 23	2659·8	4	5, 11
4312·0	4	7, 53	3113·8	5	2, 23	2638·6	5	0, 7
4129·5	4	0, 44	3105·1	5	1, 22	2615·6	4	6, 10
4074·8	4	0, 43	3077·6	4	2, 22	2588·0	4	6, 9
3188·4	4	2, 25	3033·2	4	1, 20	2554·4	5	0, 4
3159·3	4	3, 25	2998·3	5	1, 19	2420·1	4	5, 2
3150·6	5	2, 24	2963·9	4	1, 18			

SYSTEM C, λλ3390–2980

λ	I	v′, v″
3235·9	3	0, 28
3198·2	3	0, 27

SYSTEM D, λλ5580–3760

λ	I	v′, v″
4317·9	3	2, 5
3870·5	3	5, 1

Bands observed by Winand (*Bull. de la classe des sciences, Acad. Roy. de Belgique* (5), **18,** 422 (1932)) in a high-frequency discharge have been identified with CO by Almy and Kinzer.

As_2^+

Occurrence. In discharge tube containing arsenic vapour, with hydrogen to carry the discharge.

Appearance. Degraded to the violet.

Reference. G. D. Kinzer and G. M. Almy, *P.R.*, **52,** 814. (1937)†.

The following are the strong bands as listed by Kinzer and Almy. The bands are attributed to the ionised molecule because of their doublet character. Intensities on a scale of 3.

λ	I	v′, v″	λ	I	v′, v″
6550·5	2	0, 3 i	6115·2	2	0, 0 ii
6482·3	2	0, 3 ii	6051·3	3	1, 0 i
6422·0	2	0, 2 i	5992·6	3	1, 0 ii
6356·0	2	0, 2 ii	5932·7	2	2, 0 i
6297·3	2	0, 1 i	5926·2	2	3, 1 i
6234·4	2	0, 1 ii	5875·9	3	2, 0 ii
6176·8	2	0, 0 i	5869·4	2	3, 1 ii

AsN

Occurrence. In heavy-current discharge tubes containing arsenic and nitrogen.

Appearance. Degraded to the red. The bands presumably have close double heads.

Transition. Probably $^1\Pi \rightarrow {}^1\Sigma$.

Reference. J. W. T. Spinks, *Z.P.*, **88,** 511. (1934)†.

AsN (*contd.*)

The following are the bands as listed by Spinks :—

λ	I	v′, v″	λ	I	v′, v″
3051·0	2	0, 3	2784·2	10	0, 0
3007·8	1	3, 5	2719·5	7	1, 0
2884·7	3	1, 2	2675·6	4	3, 1
2868·7	6	0, 1	2656·5	5	2, 0
2833·5	1	3, 3	2602·0	2	3, 0

AsO

Occurrence. Carbon arc in air with arsenic salts on poles, high-tension arc between metallic arsenic electrodes, and in discharge tube containing As_2O_3.

References. F. C. Connelly, *Proc. Phys. Soc.*, **46**, 790. (1934)†.
F. A. Jenkins and L. A. Strait, *P.R.*, **47**, 136. (1935)†.

SYSTEM A, λλ3450–2950

Appearance. Degraded to red. Evenly spaced bands with close double heads.

Transition. $A^2\Sigma \rightarrow {}^2\Pi$, ground state.

Strong heads only, as measured by Connelly. Intensities on scale of 9.

λ	I	v′, v″	λ	I	v′, v″
3310·7	4	1, 1 ii Q	3172·4	8	0, 0 i Q
3279·1	9	0, 0 ii Q	3170·6	5	0, 0 i R
3277·2	8	0, 0 ii R	3144·1	4	2, 0 ii Q
3241·4	4	2, 1 ii Q	3137·2	4	2, 1 i Q
3209·1	6	1, 0 ii Q	3135·6	4	2, 1 i R
3207·8	4	1, 0 ii R	3106·8	6	1, 0 i Q
3202·0	4	1, 1 i Q	3105·6	4	1, 0 i R

SYSTEM B, λλ2800–2350

Appearance. Degraded to shorter wave-lengths. Marked sequences of close double-headed bands.

Transition. $B^2\Sigma \rightarrow {}^2\Pi$, ground state.

Strong bands only, by Connelly. Intensities on scale of 9 for (0, 0) band of system A.

λ	I	v′, v″	λ	I	v′, v″
2635·5	4	0, 1 ii P	2504·7	6	0, 0 i P
2634·4	5	0, 1 ii Q	2503·6	7	0, 0 i Q
2624·7	4	1, 2 ii Q	2438·5	3	1, 0 i P
2570·9	6	0, 0 ii P	2437·3	4	1, 0 i Q
2569·7	8	0, 0 ii Q			
2565·2	4	0, 1 i Q			

AuCl

Occurrence. Gold chloride in active nitrogen.

Appearance. Two overlapping systems in the green, both degraded to the red.

Transition. Both systems have common final level, probably the ground state.

Reference. W. F. C. Ferguson, *P.R.*, **31**, 969. (1928)†.

Strong bands only. Intensities on a scale of 5.

AuCl (*contd.*)

System A

λ	I	v′, v″	λ	I	v′, v″
5590·2	2	1, 4	5346·6	5	0, 1
5570·4	2	0, 3	5240·0	5	0, 0
5476·0	2	1, 3	5155·9	4	1, 0
5456·8	4	0, 2	5075·0	1	2, 0

System B

λ	I	v′, v″	λ	I	v′, v″
5531·7	1	0, 3	5205·5	5	0, 0
5437·6	2	1, 3	5121·9	4	1, 0
5419·4	3	0, 2	5041·7	1	2, 0
5310·6	5	0, 1			

AuH

References. E. Bengtsson, *Ark. f. Mat. Astron. och Fysik,* **18**, 27. (1925).
T. Heimer, *Z.P.*, **104**, 303. (1937).

3656 A. System, $^1\Sigma \rightarrow {}^1\Sigma$

Bands with single R and P branches degraded to the red. Occurs in gold arc in hydrogen.

Origins		Heads	
v′, v″	λ	R.	(I.)
0, 3	4772·2		
1, 3	4444·1	4436·6	2
0, 2	4347·8	4339·4	3
1, 2	4073·7	4068·2	3
0, 1	3978·9	3972·8	10
1, 1	3748·1		
0, 0	3656·0	3651·5	9
1, 0	3460·2	3457·4	2
2, 0	3300·3		
3, 0	3171·4		

2615 A. System, $^1\Sigma \rightarrow {}^1\Sigma$

Bands degraded to the red with single P and R branches.

Origins	
v′, v″	λ
0, 2	2950·0
0, 1	2776·0
0, 0	2614·8

B_2

Occurrence. Boron trichloride in active nitrogen.

Reference. A. E. Douglas and G. Herzberg, *P.R.*, **57**, 752. (1940).

Two sequences of bands of $\Sigma \rightarrow \Sigma$ type in region 3300–3170 A.

$$\nu = 30546{\cdot}1 + (929{\cdot}3\,v' - 2{\cdot}75\,v'^2) - (1035{\cdot}2\,v'' - 9{\cdot}08\,v''^2)$$

BBr

Occurrence. In electrodeless high-frequency discharge through BBr_3 and in absorption.
Appearance. Bands degraded in each direction.
Transition. Probably $^1\Pi \rightarrow {}^1\Sigma$, ground state.
Reference. E. Miescher, *Helvetica Phys. Acta*, **8**, 279. (1935)†.

Prominent heads as listed by Miescher. The letters R or V following the wave-length indicate that the head is degraded to longer or shorter wave-lengths respectively.

λ	I	v′, v″	λ	I	v′, v″
3094·5 R	5	3, 5 Q	2954·4 V	10	1, 1 Q
3082·7 R	5	2, 4 Q′	2954·0 R	10	1, 1 Q′
3010·3 V	5	0, 1 P	2951 —	8	0, 0 P
2973·0 R	7	3, 3 R	2948·1 V	10	0, 0 Q
2963·1 R	8	2, 2 Q	2944·2 R	9	0, 0 Q′
2959·9 R	7	2, 2 R	2935·7 R	7	0, 0 R

BCl

Occurrence. In high-frequency electrodeless discharge through BCl_3.
Appearance. Bands degraded in each direction.
Transition. Probably $^1\Pi \rightarrow {}^1\Sigma$, ground state.
Reference. E. Miescher, *Helvetica. Phys. Acta.*, **8**, 279. (1935)†.

Prominent heads as listed by Miescher. The letters R and V following the wave-length indicate that the head is degraded to longer or shorter wave-lengths respectively.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2880·6 R	6	7, 9 Q	2786·7 V	8		2723·6 R	8	2, 2 ?
2867·1 R	7	5, 7 R	2786·4 R	8		2722·2 V	10	0, 0 P
2860·4 R	10	5, 7 Q	2784·4 V	8		2721·7 V	10	1, 1 Q
2859·2 R	8	5, 7 Q*	2784·1 V	8		2720·0 V	10	0, 0 Q
2857·3 R	7		2783·7 V	9		2714·2 R	8	
2847·5 V	7		2733·3 R	9	4, 4 Q	2669·7 R	8	3, 2 Q
2847·3 V	7		2727·8 V	9	3, 3 Q	2665·3 V	9	2, 1 Q
2796·1 R	8	4, 5 Q**	2727·4 R	10	3, 3 Q′	2664·9 R	9	2, 1 Q′
2792·7 R	8	4, 5 Q	2727·2 R	8	3, 3 Q′*	2660·2 V	8	1, 0 Q**
2792·4 R	9	4, 5 Q′	2724·0 V	10	2, 2 Q	2659·8 R	8	1, 0 Q′**

* Head due to isotope $B^{11}Cl^{35}$.
** Head due to isotope $B^{10}Cl^{37}$.
Other bands due to $B^{11}Cl^{37}$.

Bands whose analysis is not given are due to the piled up (0, 2), (0, 1) or (0, 0) sequences, the bands of which are very close at the head of the sequence.

BF

There are two systems of bands in the visible which have not been analysed and two systems in the ultra-violet.
Occurrence. In discharge tubes containing BF_3, and especially in a high-frequency electrodeless discharge for the ultra-violet systems.
References. R. B. Dull, *P.R.*, **47**, 458. (1935)†.
H. M. Strong and H. P. Knauss, *P.R.*, **49**, 740. (1936)†.

BF (*contd.*)

YELLOW SYSTEM, λλ6400–5646

Appearance. Diffuse bands degraded to the violet.

Strong heads as listed by Dull :—

λ	I	λ	I
5993·8	8	5815·1	8
5984·4	6	5807·3	6
5825·7	7	5803·8	6
5822·1	10	5664·0	6

BLUE-GREEN SYSTEM, λλ5476–4439

Appearance. Diffuse bands degraded to the red.

Strong bands as listed by Dull :—

λ	I	λ	I
5470·8	6	4464·9	8
5460·1	4*	4461·4	6
5456·8	8	4443·5	6

* Intensity given as 10 by Johnson and Tawde.

ULTRA-VIOLET SYSTEMS

Appearance. Degraded to shorter wave-lengths. Bands with five heads, similar in appearance to the CO third positive bands.

Transition. Two systems with a common lower level, probably either $^3\Pi \rightarrow {}^3\Sigma$ or $^3\Sigma \rightarrow {}^3\Pi$.

System A. All five heads of the (0, 0) band and the P_3 heads of the other strong bands as listed by Strong and Knauss.

λ	I	v′, v″	λ	I	v′, v″
3549·8	4	0, 3	3124·1	2	0, 0 O
3396·9	3	0, 2	3122·1	7	P_3
3359·7	2	1, 3	3121·2	9	P_2
3254·8	5	0, 1	3120·3	9	P_1
3222·9	1	1, 2	3118·4	9	Q_1
			2974·8	4	1, 0
			2844·5	2	2, 0

System B. Similar to above. P_3 heads of the three bands given by Strong and Knauss.

λ	I	v′, v″
2824·0	3	0, 2
2724·9	4	0, 1
2631·4	7	0, 0

BH

References. S. F. Thunberg, *Z.P.*, **100,** 471. (1936).
G. M. Almy and R. B. Horsfall, *P.R.*, **51,** 491. (1937).

BH (*contd.*)

4332 A. SYSTEM, $^1\Pi \rightarrow {}^1\Sigma$

Bands degraded to the red consisting of single P, Q and R branches. The Q head is very intense through superposition of several lines.

Observed in hollow cathode containing boron and hydrogen and from a discharge through a mixture of hydrogen and BCl_3.

v′, v″	Q Heads	R Heads
0, 0	4331·6	4245·9
1, 1	4367·3	4319·2
2, 2	4433·7	

3662 A. SYSTEM, $^3\Sigma \rightarrow {}^3\Pi$

Bands obtained under similar conditions to those described above. Degraded to the red.

v′, v″	Q Head	R Head
0, 0	3693·8	3662·4

Further bands at 3415 A. and 3100 A. have been reported by Douglas and Herzberg.

Reference. A. E. Douglas and G. Herzberg, *P.R.*, **57**, 752. (1940).

BH⁺

References. G. M. Almy and R. B. Horsfall, *P.R.*, **51**, 491. (1937).

3768 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$

Bands showing P, Q and R branches degraded to the red, each consisting of narrow doublets. Obtained with a hollow cathode of the Schüler type containing boron, hydrogen and helium.

v′, v″	R Heads	Q Head
0, 0	3768·1	3792
1, 1	3803	

BN

Reference. See B_2.

Bands at 3600 and 3225 A. in discharge through helium containing boron trichloride and nitrogen are probably due to BN.

BO

There are two strong band systems attributed to boron monoxide, usually known as the α and β systems, and a third weak intercombination system.

α SYSTEM, λλ8519–3136

Occurrence. In arcs containing B_2O_3 and boron arc in air. The bands are also very well developed when a volatile boron compound such as BCl_3 is introduced into active nitrogen containing a trace of oxygen.

Appearance. Degraded to the red. Double double-headed bands (see Plate 6).

Transition. A $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. R. S. Mulliken, *P.R.*, **25**, 259. (1925)†.

F. A. Jenkins and A. McKellar, *P R*, **42**, 464. (1932)†.

BO (*contd.*)

The strong heads are listed below Intensities, by Mulliken, are for BCl_3 in active nitrogen Only data for $B^{11}O$ are given.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
6165·4	5	0, 4 Q_1	4585·7	7	0, 1 R_{21}	3950·5	4	3, 1 Q_1
6159·7	5	0, 4 R_1	4365·9	8	1, 1 Q_1	3848·7	10	2, 0 Q_1
5551·5	8	0, 3 Q_1	4363·4	10	1, 1 R_1	3847·0	9	2, 0 R_1
5547·5	7	0, 3 R_1	4341·9	8	1, 1 R_2	3829·9	8	2, 0 R_2
5513·0	5	0, 3 R_2	4339·4	8	1, 1 R_{21}	3828·0	6	2, 0 R_{21}
5043·5	6	0, 2 Q_1	4250·4	5	0, 0 Q_1	3679·1	10	3, 0 Q_1
5040·1	9?	0, 2 R_1	4247·9	4	0, 0 R_1	3677·8	8	3, 0 R_1
5011·6	4	0, 2 R_2	4227·5	4	0, 0 R_2	3662·3	6	3, 0 R_2
4746·9	8	1, 2 Q_1	4145·5	7	2, 1 Q_1	3660·6	5	3, 0 R_{21}
4744·0	8	1, 2 R_1	4143·4	6	2, 1 R_1	3526·8	7	4, 0 Q_1
4718·7	5	1, 2 R_2	4124·1	4	2, 1 R_2	3525·5	7	4, 0 R_1
4715·5	5	1, 2 R_{21}	4037·4	8	1, 0 Q_1	3511·3	6	4, 0 R_2
4615·4	10	0, 1 Q_1	4035·5	7	1, 0 R_1	3510·0	5	4, 0 R_{21}
4612·7	10	0, 1 R_1	4017·1	6	1, 0 R_2	3389·1	5	5, 0 Q_1
4588·8	8	0, 1 R_2	4015·0	5	1, 0 R_{21}	3387·6	7	5, 0 R_1
						3374·7	5	5, 0 R_2

β System, λλ3645–2120

Occurrence. As for α system.

Appearance. Degraded to the red. Single-headed bands.

Transition. B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

Reference. R. S. Mulliken, *P.R.*, **25**, 259. (1925)†.

The strong bands as obtained by Mulliken in active nitrogen are listed below. The more abundant isotope $B^{11}O$ only is given.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3493·1	4	4, 11	2934·9	9	3, 7	2551·4	9	0, 2
3441·6	6	3, 10	2892·2	10	2, 6	2544·3	7	3, 4
3391·2	5	2, 9	2850·6	8	1, 5	2507·7	6	2, 3
3354·6	5	5, 11	2809·9	8	0, 4	2472·0	5	1, 2
3305·4	8	4, 10	2793·9	7	3, 6	2437·1	10	0, 1
3256·9	9	3, 9	2753·4	9	2, 5	2433·3	6	3, 3
3209·3	7	2, 8	2713·8	10	1, 4	2398·5	10	2, 2
3134·6	6	4, 9	2703·4	4	4, 6	2364·5	8	1, 1
3088·6	9	3, 8	2675·3	8	0, 3	2331·3	7	0, 0
3043·6	9	2, 7	2664·1	4	3, 5	2330·4	6	3, 2
2999·7	7	1, 6	2625·6	6	2, 4	2264·8	6	1, 0
2978·5	6	4, 8	2588·0	8	1, 3	2234·6	4	3, 1
2956·6	6	0, 5	2581·6	4	4, 5	2203·0	4	2, 0

Combination System

Occurrence. BCl_3 in active nitrogen containing oxygen.

Appearance. This is a weak system and is usually masked by the overlapping α system. The bands are not clearly degraded, but some are shaded slightly to the violet (see Plate 6).

Transition. B $^2\Sigma \rightarrow$ A $^2\Pi$, upper state of α system.

Reference. R. S. Mulliken, *P.R.*, **25**, 259. (1925)†.

BO (*contd.*)

The following are the strongest bands as listed by Mulliken :—

λ	I	v′, v″	λ	I	v′, v″
5916·2	1*	0, 2 B_1	5155·5	1	2, 2 B_1
5895·3	½	1, 3 B_1	4881·2	4*	1, 0 2,1 3,2 A_1
5493·7	½	2, 3 B_1	4850·9	5	1, 0 2,1 3,2 B_1
5201·1	1	0, 0 A_1	4580·8	1	3, 1 B_1
5189·3	1	2, 2 A_1	4576·5	½	2, 0 A_1

* Masked by α band.

B_xO_y

Waves of close narrow bands are observed when boric acid is introduced into an arc.

Reference. W. Jevons, *P.R.S.*, **91**, 120. (1915)†.

Maxima of "waves" λλ6390, 6200, 6030, 5800, 5450, 5180, 4930, 4710 and 4520. These appear to be due to the superposition of bands of the α System and bands of the Combination System (see Plate 6).

BaBr

Occurrence. When barium bromide is introduced into a flame or arc, and in absorption.

Appearance. Marked close sequences ; the rotational structure appears to be degraded to the red, while the vibrational structure is degraded to the violet.

Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. K. Hedfeld, *Z.P.*, **68**, 610. (1931).
O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).

The following measurements of the heads of the sequences are by Hedfeld. Intensities I_a and I_e are for absorption and emission in an arc respectively, the former being by Walters and Barratt.

λ	I_a	I_e	Sequence
5415·9	7	4	0, 1 i
5360·1	10	10	0, 0 i
5305·5	6	2	1, 0 i
5260·6	4	2	0, 1 ii
5208·2	10	10	0, 0 ii
5156·4	5	1	1, 0 ii

BaCl

There is a strong system of bands in the green, and there are also two weak systems in the near ultra-violet.

GREEN SYSTEM

Occurrence. Barium chloride in carbon arc or flame, and in absorption.

Appearance. The system is only slightly degraded, and hence the heads are rather indefinite, the rotational and vibrational structure being degraded in opposite directions for some sequences.

BaCl (*contd.*)

Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928)†.
K. Hedfeld, *Z.P.*, **68**, 610. (1931).
A. E. Parker, *P.R.*, **46**, 301. (1934)†.

The analyses proposed by Hedfeld and by Parker differ in some details. The following are probably the most obvious points for measurement under low dispersion. The letters R and V indicate that the sequences are degraded to longer or shorter wave-lengths.

λ	I	Sequence
5320·8 V	3	0, 1 i
5240·5 R	10	0, 0 i
5213 V	1	0, 1 ii
5167 R	2	1, 0 i
5139·2 V / 5136 R	10	0, 0 ii
5066 V	1	1, 0 ii

Ultra-violet Systems

Occurrence. In arc.

Reference. A. E. Parker, *P.R.*, **46**, 301. (1934)†.

Longer wave-length system, probably $^2\Sigma \rightarrow {}^2\Sigma$, ground state, marked sequences degraded to shorter wave-lengths. The following appear to be the three strongest sequences as seen in the published photographs :—

λ	Sequence
3923·0	0, 0
3876·8	1, 0
3832·0	2, 0

Shorter wave-length system, probably also $^2\Sigma \rightarrow {}^2\Sigma$, ground state, degraded to shorter wave-lengths. Strongest sequences :—

λ	Sequence
3691·7	0, 0
3649·9	1, 0

BaF

Occurrence. When BaF_2 is introduced into carbon arc or a flame. Also in absorption.

References. S. Datta, *P.R.S.*, **99**, 436. (1921)†.
T. E. Nevin, *Proc. Phys. Soc.*, **43**, 554. (1931)†.
F. A. Jenkins and A. Harvey, *P.R.*, **39**, 922. (1932)†.

There are four systems, in the ultra-violet, green, extreme red and infra-red.

Ultra-violet System, λλ4136–3650. Observed in absorption only

Appearance. Degraded to shorter wave-lengths.

Transition. D (unknown) to $^2\Sigma$, ground state.

BaF (*contd.*)

Strongest bands as measured by Jenkins and Harvey :—

λ	I	v′, v″
4135·8	4	0, 0 ii
3878·6	3	0, 1 i
3809·9	10	0, 0 i
3804·5	5	1, 1 i
3738·3	6	2, 2 i

GREEN SYSTEM, λλ5139–4842

Appearance. Degraded to red. Close-marked sequences with " tails." Appearance best given by Datta's photograph.

Transition. C $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Strongest heads of sequences. Own estimates of intensity from published photographs.

λ	I	Sequence
5000·6	8	0, 0 Q_1
4992·1	5	0, 0 R_1
4950·8	10	0, 0 R_2

EXTREME RED SYSTEM, λλ7734–6716

Appearance. Degraded to longer wave-lengths. Double-headed bands.

Transition. B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

R_2 and R_1 heads of strong bands. Intensities on scale of 8.

λ	I	v′, v″
7430·8 7426·9	6	3, 4
7142·0 7138·8	8	1, 1
7119·2 7116·0	8	0, 0
6958·7 6955·9	5	3, 2
6935·1 6932·5	5	2, 1

INFRA-RED SYSTEM, 8738–7862

Appearance. Degraded to longer wave-lengths. Marked sequences.

Transition. A $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Strong bands only. Intensities on scale of 8.

λ	I	v′, v″
8618·8	7	2, 2 i Q
8595·3	8	1, 1 i Q
8571·5	7	0, 0 i Q
8193·6	8	2, 2 ii Q
8172·3	8	1, 1 ii Q
8158·7	7	1, 1 ii R
8151·0	8	0, 0 ii Q
8137·0	7	0, 0 ii R

BaH

References. W. W. Watson, *P.R.*, **47,** 213. (1935).
P. G. Koontz and W. W. Watson, *P.R.*, **48,** 937. (1935).

10,000 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$

Bands degraded to the red, obtained with an arc between a copper anode and a copper cathode filled with metallic barium in an atmosphere of hydrogen.

v′, v″	Heads $^2\Pi_{3/2} \rightarrow {}^2\Sigma$		$^2\Pi_{1/2} \rightarrow {}^2\Sigma$	
0, 0	R_2	10,052	Q_1	10,746·4
			R_1	10,603·3

8924 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$

Bands with P and R branches degraded to the red.

v′, v″	Heads R_1	R_2
1, 0	8240	8187
2, 1	8318	8267
0, 0	9017	8924
1, 1	9086	

References. G. W. Funke, *Z.P.*, **84,** 610. (1933).
A. Schaafsma, *Z.P.*, **74,** 254. (1932).
W. R. Fredrickson and W. W. Watson, *P.R.*, **39,** 753 (1932).

6700 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$

System of complex bands degraded to the violet obtained in barium arc in hydrogen at reduced pressure.

v′, v″	$^OP_{12}$	P_1	Heads $^PQ_{12}$	P_2	$^QP_{12}$	Q_2
0, 1	7481	7423	7422	7222	—	7174
0, 0	6923·5	6850·2	6848·6	6689·5	6635·1	6634·3
1, 1	—	6827·4	6825·8	6665·0	6610·8	6610·0
1, 0	—	—	—	—	6152·4	6151·2

Reference. G. W. Funke and B. Grundström, *Z.P.*, **100**, 293. (1936.)

4228 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$

Weak bands degraded to the violet obtained in absorption and emission.

	Origins	P. Heads
0, 1	4440	
0, 0	4228	4227·1
1, 1	4201	4202·2
1, 0	4014	
2, 0	4000	

BaI

There is a band system in the green and a weaker system in the ultra-violet.

Green System

Occurrence. In absorption and in flames.
Appearance. Degraded to shorter wave-lengths.
References. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).
C. M. Olmsted, *Zeit. f. wissen. Photographie*, **4**, 255. (1906).

Measurements by Walters and Barratt. Intensities I_a and I_f are for absorption and emission in a flame respectively, the latter being by Olmsted.

λ	I_a	I_f
5609·5	10	10
5381·7	10	7
5260	0	
5160	0	

Ultra-violet Bands

Occurrence. In absorption.
Appearance. Degraded to shorter wave-lengths.

Bands as observed by Walters and Barratt :—

λ	I
3830	1
3804	2
3778	3
3756	3
3736	1

BaO

Occurrence. When barium salts are introduced into carbon arc or flame.
Appearance. Degraded to longer wave-lengths.
Transition. $^1\Sigma \rightarrow {}^1\Sigma$, probably ground state.
Reference. P. C. Mahanti, *Proc. Phys. Soc.*, **46**, 51. (1934)†.

The system extends from λ7905 to λ4269. Only the strong bands are listed below.

λ	I	v′, v″	λ	I	v′, v″
7097·4	5	0, 4	5805·1	6	1, 0
6782·8	8	0, 3	5701·0	8	3, 1
6493·1	9	0, 2	5644·1	9	2, 0
6291·0	8	1, 2	5492·7	10	3, 0
6224·7	6	0, 1	5349·7	8	4, 0
6165·1	6	3, 3	5214·7	7	5, 0
6102·3	5	2, 2	5086·7	6	6, 0
6039·6	9	1, 1	4965·4	3	7, 0
5976·3	3	0, 0	4850·6	6	8, 0
5864·5	10	2, 1	4680·3	5	11, 1

BeCl

Occurrence. Beryllium arc in chlorine.
Appearance. Degraded to the red. Marked sequences.
Transition. $^2\Pi \rightarrow {}^2\Sigma$, probably ground state.
Reference. W. R. Fredrickson and M. E. Hogan, *P.R.*, **46**, 454. (1934)†.

The following are the outstanding heads ; the intensities are our own estimates from the published photographs :—

λ	I	v′, v″
3676·8	6	0, 1 R_1
3575·7	9	0, 0 Q_1
3570·9	10	0, 0 R_2
3567·0	10	0, 0 R_1
3559·2	1	0, 0 $^SR_{21}$
3468·3	4	1, 0 R_1

BeF

Occurrence. Beryllium fluoride in carbon arc.
Appearance. Degraded to red. Marked sequences.
Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.
References. W. Jevons, *P.R.S.*, **122**, 211. (1929)†.
F. A. Jenkins. *P.R.*, **35**, 315. (1930)†.

Bands in ultra-violet, λλ3393–2816. Strongest bands only listed. The R_2 heads only are given except for (0, 0) band. Own intensities from published photographs.

λ	I	v′, v″	
3126·1	8	0, 1	
3018·0	9	1, 1	
3013·0	6	0, 0	Q_1
3009·9	10		R_1
3009·6	9		R_2
2909·0	7	1, 0	
2816·0	3	2, 0	

BeH

References. W. W. Watson, *P.R.*, **32**, 600. (1928).
E. Olsson, *Z.P.*, **73**, 732. (1932).
W. W. Watson and R. F. Humphreys, *P.R.*, **52**, 318. (1937).

4988 A. System, $^2\Pi \rightarrow {}^2\Sigma$, Ground State

Bands show P, Q and R branches degraded at first to the violet but turning to the red at high values of the rotational quantum number.

Obtained in arc between beryllium poles in hydrogen at a few cms. pressure.

v′, v″	Origins	Q Heads
0, 1	5537·2	
1, 2	5507·9	
0, 0	4988·3	4990·8
1, 1	4983·3	4985·7
2, 2	4980·5	4982·8

BeH (*contd.*)

1960 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$, GROUND STATE

Principal feature of this system is a single strong Q branch degraded to short wavelengths from a head at 1960 A.

Obtained in a hollow cathode of molybdenum and in a beryllium arc in hydrogen.

v′, v″	Q Heads
0, 0	1960
1, 1	1956
1, 0	1882

BeH^+

References. W. W. Watson and R. F. Humphreys, *P.R.*, **52**, 318. (1937).
W. W. Watson, *P.R.*, **32**, 600. (1928).

2559 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$, GROUND STATE

An extensive system of singlet bands degraded to the red. Obtained from an arc between beryllium electrodes in hydrogen at low pressures.

v′, v″	R Heads
2, 0	2384·6
1, 0	2468·1
0, 0	2559·4
0, 1	2707·4
1, 3	2910·9
0, 3	3039·6
1, 4	3081·8

BeO

There are four systems of bands attributed to beryllium oxide. There is a strong system in the blue-green, a moderately intense system in the far red, and two weak systems in the ultra-violet.

Occurrence. Beryllium salts in carbon arc, arc between beryllium electrodes in air, and in uncondensed spark between Be electrodes.

References. E. Bengtsson, *Ark. Mat. Astr. Fys.*, **20**A, No. 28. (1928).
L. Herzberg, *Z.P.*, **84**, 571. (1933)†.
A. Harvey and H. Bell, *Proc. Phys. Soc.*, **47**, 415. (1935).

BLUE-GREEN SYSTEM, λλ5488–5427

Appearance. Degraded to red. Marked sequences of single-headed bands.

Transition. $C^1\Sigma \rightarrow {}^1\Sigma$, ground state.

Strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
5113·0	5	3, 4	4732·7	7	1, 1
5094·6	7	2, 3	4708·7	10	0, 0
5075·2	7	1, 2	4474·8	6	3, 2
5054·1	5	0, 1	4451·8	6	2, 1
4754·5	4	2, 2	4427·3	5	1, 0

BeO (*contd.*)

RED SYSTEM

Appearance. Degraded to longer wave-lengths. Double-headed bands, but with the R heads rather faint and diffuse.

Transition. B $^1\Pi \rightarrow {}^1\Sigma$, ground state.

The origins of the strong bands are listed below. The wave-lengths of the heads have not been published, but the origins and Q heads are only about 1 or 2 Angstroms apart. Intensities on a scale of 6.

λ_0	I	v′, v″
7953·3	6	2, 0
7324·8	3	3, 0
6523·5	4	6, 1
6344·4	3	5, 0
6286·9	3	8, 2
6117·8	3	7, 1

BENGTSSON'S ULTRA-VIOLET SYSTEM

Degraded to red. E ($^1\Pi$?) $\rightarrow$ B$^1\Pi$, upper level of red system.
Strong heads :—

λ	I	v′, v″
3367·6	2	0, 2
3258·1	3	1, 2
3247·7	3	0, 1
3145·7	3	1, 1
3134·0	3	0, 0

HARVEY AND BELL'S ULTRA-VIOLET SYSTEM

Degraded to red. D ($^1\Pi$?)$\rightarrow$ B$^1\Pi$, upper level of red system. No intensities given. The following are probably the strongest bands :—

λ	v′, v″
3496·0	0, 1
3371·1	1, 1
3363·7	0, 0
3247·6	1, 0

There is also a head not accounted for at λ3368.

Bi_2

Four systems of bands have been attributed to diatomic bismuth.

References. G. M. Almy and F. M. Sparks, *P.R.*, **44**, 365. (1933)†.
G. Nakamura and T. Shidei, *Japan Jour. Phys.*, **10**, 11. (1935)†.

VISIBLE SYSTEM, $\lambda\lambda$7910–4500

Occurrence. In absorption, in emission (in furnace), and fluorescence.

Appearance. Degraded to the red.

Transition. B $\rightarrow$ A, ground state (probably $^1\Sigma$).

Bi_2 (*contd.*)

The following are the strongest bands as listed by Nakamura and Shidei, in absorption :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5679·9	5	3, 3	5453·8	7	6, 1	5293·4	10	9, 0
5625·2	5	3, 2	5415·5	7	7, 1	5258·2	10	10, 0
5531·2	5	4, 1	5365·5	8	7, 0	5224·1	10	11, 0
5491·9	7	5, 1	5329·5	8	8, 0	5190·3	9	12, 0

Violet System, λλ4200–4000

Occurrence. In absorption at high temperature.

Appearance. Degraded to the red.

Transition. D ←B, upper state of visible system.

Strongest bands as observed by Almy and Sparks :—

λ	I	v′, v″
4150·7	4	0, 3
4128·0	5	0, 2
4105·5	5	0, 1
4064·5	2	1, 0

Ultra-violet System, λλ2900–2600

Occurrence. In absorption. This system appears to come up very easily and has been observed as an impurity especially in cadmium.

Transition. C←A, ground state.

Strong bands as recorded by Almy and Sparks :—

λ	I	v′, v″	λ	I	v′, v″
2810·2	5	1, 6	2755·9	4	0, 1
2796·9	7	1, 5	2744·5	6	1, 1
2783·7	5	1, 4	2731·6	9	1, 0
2782·2	4	0, 3	2720·7	7	2, 0
2768·9	7	0, 2	2710·3	5	3, 0

Far Ultra-violet System, λλ2250–2000

Weak diffuse bands observed in absorption ; probably from ground state. Strong bands as observed by Almy and Sparks, λλ2205·4, 2197·2, 2188·8, 2180·5, 2172·7, 2148·8, 2142·9, and 2135·8.

BiBr

There are two systems observed in absorption.

λλ4130–3862. Bands not clearly degraded either way ; strong flutings from 4041 A getting weaker to shorter wave-lengths.

λλ5438–4595. Weaker bands degraded to red. Strongest head at 5246·5 A.

Reference. F. Morgan, *P.R.*, 49, 41. (1936)†.

BiCl

Two systems have been observed in absorption.

λλ3995–3787. Bands degraded to red, but flutings getting weaker to shorter wave-lengths. Strong (0, 0) band at 3914·3 A.

λλ5500–4300. Most of the bands degraded to the red. Strongest heads 4614·4, 4569·9, 4465·4 A.

Reference. F. Morgan, *P.R.*, 49, 41. (1936)†.

BiF

System A

Occurrence. High-frequency discharge through BiF_3 vapour, and in absorption.
Reference. H. G. Howell, *P.R.S.*, **155**, 141. (1936)†.
Bands degraded to red. Heads of strongest sequences :—

λ	I	Sequence
4568·2	8	0, 2
4465·5	10	0, 1
4366·7	10	0, 0
4295·8	8	1, 0

System B

A weak system in the violet reported as occurring in absorption.
Reference. F. Morgan, *P.R.*, **49**, 41. (1936).

System C

A triplet system degraded to the red obtained in active nitrogen.
Reference. G. D. Rochester, *P.R.*, **51**, 486. (1937).
Strongest heads : λλ3107, 2743, 2705, 2284.

BiH

Reference. A. Heimer, *Z.P.*, **95**, 328. (1935)†.
Occurrence. The band systems described below have been obtained in the bismuth arc in hydrogen at reduced pressure and in discharge tubes containing bismuth vapour and hydrogen.

4698 A. System, $^1\Sigma^* \rightarrow {}^1\Sigma$

Bands slightly degraded to the violet. Strongest system :—

Origins λ	v′, v″
4361	1, 0
4698	0, 0
4697	1, 1
5071	1, 2
5089	0, 1

P branch closes up to a weak head near 4736 A. just beyond the strong Bi line 4722 A.

6118 A. System, $^1\Sigma^* \rightarrow {}^1\Pi$

Bands slightly degraded to the violet.

Origins λ	v′, v″	Heads
6118	0, 0	6117·5 Q
6792	1, 2	6792·2 Q
6814	0, 1	6813·5 Q

4842 A. System, $^1\Sigma_x \rightarrow {}^1\Sigma_y$

Bands slightly degraded to the red. Weak system.

Origins λ	v′, v″
4842	0, 0
5171	0, 1

BiI

Bands λλ4308–4164 have been observed in absorption ; some are deg
each direction ; (0, 0) band at λ4271·2.

Reference. F. Morgan, *P.R.*, **49**, 41. (1936)†.

BiO

Occurrence. In flames and arcs containing bismuth salts.

Appearance. Four systems, all degraded to the red.

Reference. C. Ghosh, *Z.P.*, **86**, 241. (1933)†.

The following measurements of the strong bands of the four systє
Ghosh. The intensities are our estimates from Ghosh's published pho

System A, λλ4853–4316

λ	I	v′, v″	λ	I	v′, v″
4745·1	6	0, 3	4549·9	8	0, 0
4678·9	7	0, 2	4507·2	10	1, 0
4613·8	10	0, 1	4466·2	7	2, 0
4569·9	9	1, 1			

System B, λλ5274–4657

λ	I	v′, v″
4938·6	7	0, 3
4866·9	7	0, 2
4796·5	8	0, 1
4727·4	10	0, 0

System C, λλ5840–5168

λ	I	v′, v″
5662·9	4	0, 1
5547·6	4	0, 0
5464·1	4	1, 0

System D, λλ6617–5587

λ	I	v′, v″
6411·7	6	0, 3
6218·3	8	0, 2
6035·2	10	0, 1
5931·9	8	1, 1
5861·7	10	0, 0
5764·1	6	1, 0

Br_2

Main (Absorption) System

Occurrence. This system occurs readily in absorption by bromine vapour. It has also been observed by Uchida in emission from the heated vapour, by Kitagawa in the flame of bromine burning in hydrogen and by Vaidya in the flame of ethyl bromide.

Appearance. Degraded to the red. Very closely spaced bands extending from 5100 A. to the near infra-red. In absorption there is a continuum in the blue (commencing at the short wave limit of the band system).

Br_2 *(contd.)*

References. H. Kuhn, *Z.P.*, **39**, 77. (1926).
W. G. Brown, *P.R.*, **38**, 1179. (1931); *P R.*, **39**, 777. (1932).
O. Darbyshire, *P.R.S.*, **159**, 93. (1937)†.
Y. Uchida, *Inst. Phys. Chem. Res. Tokyo Sci. Papers*, No. 651, **71**. (1936).
T. Kitagawa, *Proc. Imp. Acad. Japan*, **11**, 262. (1936).
W. M. Vaidya, *Ind. Acad. Sci. Proc.*, **7A**, 321. (1938).

A full table of wave-lengths of the absorption bands without intensities is given by Kuhn. The following are the wave lengths (averaged from the above references) of the bands which have been observed in emission by most of the above authors. Most of these bands occur in absorption also.
λλ6546, 6472, 6415, 6364, 6342, 6312, 6291, 6263, 6239, 6220, 6189, 6168, 6120, 6071, 5957, 5942, 5864, 5826, 5752, 5725, 5603, 5588.

EMISSION BANDS

Occurrence. Observed by Uchida and Ota in an uncondensed discharge through bromine vapour.
Appearance. Degraded to longer wave-lengths.
Reference. Y. Uchida and Y. Ota, *Japan. J. Phys.*, **5**, 59. (1928)†.

The bands have been tentatively arranged into two systems. The following are the wave-lengths of the strongest bands with our estimates of the intensities made from the published photograph :—

λ	I	λ	I	λ	I	λ	I
6646	3	6392·8	6	6027·8	8	5586·1	9
6579·0	4	6372·1	5	6004·6	10	5532·4	7
6540·7	4	6332·8	6	5945·7	9	5529·2	6
6519·7	4	6282·0	6	5880·6	10	5428·6	4
6475·6	7	6217·0	7	5819·7	9	5382·6	4
6455·1	7	6144·8	8	5758·3	10	5134·2	3
6435·9	8	6083·1	8	5699·9	10	5100·7	3
6421·2	5	6074·6	8	5644·3	9		

BrO ?

ETHYL BROMIDE FLAME BANDS

Occurrence. In flame of ethyl bromide.
Appearance. Degraded to red.
Reference. W. M. Vaidya, *Indian Acad. Sci. Proc.*, **7A**, 321. (1938).

The bands are attributed to bromine monoxide by Vaidya. The following are the bands as listed by him ; the vibrational quantum numbers are only provisional and may require raising :—

λ	I	v′, v″	λ	I	v′, v″
4534·2	8	0, 4	4178·1	5	1, 2
4430·2	4	3, 4	4147·0	5	0, 1
4399·4	7	0, 3	4065·8	4	—
4269·8	7	0, 2	4029·2	3	0, 0

C_2

There are three strong band systems attributed to this molecule, the *Swan* bands sometimes known as the First Positive bands of carbon, Fowler's *High Pressure* system, and *Deslandres and d'Azambuja's* spark system. Weaker systems have been observed by *Mulliken* and by *Fox and Herzberg*.

Swan System

Occurrence. These bands are of very frequent occurrence in sources containing carbon. They are especially strongly developed in the green part of the roaring flame of a Bunsen or Meker burner, and in vacuum tube discharges of high current density through hydrocarbon vapours. They have also been observed in active nitrogen in discharge tubes containing helium and a trace of CO, and in the electric furnace.

Appearance. Degraded to violet. Single-headed. Sequences well marked. See Plate 5.

Transition. $^3\Pi \rightarrow {}^3\Pi$, probably ground state.

References. R. C. Johnson, *Phil. Trans. Roy. Soc. A.*, **226**, 157. (1927).
W. Jevons, "Report on Band Spectra of Diatomic Molecules," The Physical Society, 1932.

λ	I	v′, v″	λ	I	v′, v″
6677·3	1	2, 5	5501·9	4	3, 4
6599·2	1	3, 6	5470·3	2	4, 5
6533·7	2	4, 7	5165·2	10	0, 0
6480·5	2	5, 8	5129·3	6	1, 1
6442·3	2	6, 9	5097·7	1	2, 2
6191·2	3	0, 2	4737·1	9	1, 0
6122·1	4	1, 3	4715·2	8	2, 1
6059·7	3	2, 4	4697·6	7	3, 2
6004·9	3	3, 5	4684·8	4	4, 3
5958·7	2	4, 6	4678·6	2	5, 4
5923·4	1	5, 7	4668·7	1	6, 5
5635·5	8	0, 1	4382·5	2	2, 0
5585·5	8	1, 2	4371·4	4	3, 1
5540·7	6	2, 3	4365·2	5	4, 2

High Pressure System

It has recently been suggested (*P.R.*, **52**, 638, 1937) that these bands are part of the same system as the Swan bands, but as they can occur under different experimental conditions we have preferred to treat them separately.

Occurrence. In condensed discharge through CO at relatively high pressure (10 to 100 mm.).

Appearance. Degraded to violet. Appear double-headed with small dispersion, but under larger dispersion the shorter wave-length heads become less definite owing to resolution into line structure.

Transition. $^3\Pi \rightarrow {}^3\Pi$, ground state.

References. R. C. Johnson and R. K. Asundi, *P.R.S.*, **124**, 668. (1929).
A. Fowler, *Monthly Notices Royal Astronom. Soc.*, **70**, 484. (1910)†.

C_2 (*contd.*)

In the following table the longer wave-length heads are those given by Johnson and Asundi and the shorter wave-length heads, where given, are by Fowler. The analysis is that put forward by Johnson and Asundi, and may require revision in view of later work. Intensities on a scale of 15.

λ	I	v′, v″	λ	I	v′, v″
7852·5	4	0, 11	4680·2	15	0, 5
—			4663	6	
7083·2	6	0, 10	4368·8	7	0, 4
—			4353	3	
6442·3	8	0, 9	4093	2	0, 3
6420	4		—		
5899·3	10	0, 8	3619·5	1	0, 1
5878	5		—		
5434·9	5	0, 7	3419	1	0, 0
5413	2		—		
5030	2	0, 6			
5015	1				

Deslandres–d'Azambuja's System

Occurrence. Condensed discharge through CO, CO_2, or C_2H_2, or through argon containing hydrogen between carbon electrodes. In spark through liquid alcohol. In carbon arc in hydrogen running under high temperature conditions.
Appearance. Degraded to shorter wave-lengths.
Transition. ${}^1\Pi \rightarrow {}^1\Pi$. The position of these levels relative to the ${}^3\Pi$ ground level is unknown.
References. R. C. Johnson, *Nature*, **125**, 89. (1930).
G. H. Dieke and W. Lochte-Holtgreven, *Z.P.*, **62**, 767. (1930).

λ	I	v′, v″	λ	I	v′, v″
4102·3	9	0, 1	3607·3	8	1, 0
4068·1	6	1, 2	3592·9	7	2, 1
4041·8	3	2, 3	3587·6	7	3, 2
4026·9	1	3, 4	3399·7	5	2, 0
3852·2	10	0, 0	3398·1	5	3, 1
3825·6	5	1, 1			

Fox–Herzberg System

Occurrence. Weakly condensed discharge through helium containing benzene vapour
Appearance. Shaded to red, but no sharp heads.
Transition. ${}^3\Pi \rightarrow {}^3\Pi$, ground state.
Reference. J. G. Fox and G. Herzberg, *P.R.*, **52**, 638. (1937).

λ	I	v′, v″
2855	strong	0, 3
2987	,,	0, 4
3129	weak	0, 5
3283	,,	0, 6

C_2 *(contd.)*

Mulliken's System

References. R. S. Mulliken, *Zeit. f. Electrochemie,* **36,** 603. (1930).
J. G. Fox and G. Herzberg, *P.R.*, **52,** 638. (1937).

Headless $^1\Sigma \rightarrow {}^1\Sigma$ band at 2313·7 A. Weaker band at 2421·5 may be (0, 1) band same system. Intensity maximum at about 2325 A.

Other Bands

Reported by Fox and Herzberg (*P.R.*, **52**, 638, 1937) and possibly due to The first four bands may be tail bands of Swan system.

4996·7 R	4496·9 R	3688·7 R	3560·7 R	2218·5 V
4911·0 R	4339·6 R	3670·8 R	3506·6 R	2216·6 V
4836·1 R	4324·4 R	3618·0 R	3434·0 R	2143·0 V
4770·1 R	4147·8 R	3599·2 R	3384·4 R	

CCl

Occurrence. Uncondensed discharge through flowing CCl_4 vapour.
Reference. R. K. Asundi and S. M. Karim, *Proc. Indian Acad. Sci.*, **6A**, 328. (1937).

Continuous Bands

Long λ limit	Maximum	Short λ limit	Intensity
5850	4600	4000	Strong
4000	3348	3260	Moderate
3260	3070	3000	Strong
2700	2580	2500	Strong
2500	2430	2380	Weak
2380	2300 ?	2250	Weak

Bands Degraded to Shorter Wave-lengths

Transition. Perhaps $^2\Sigma \rightarrow {}^2\Pi$, ground state.

λ	I	v′, v″
2862·0	0	0, 1
2856·8	4	
2849·4	4	
2845·8	4	
2795·9	6	0, 0
2789·8	8	
2782·3	8	
2778·8	6	
2788·3	8	1, 1
2777·6	8	
2786·6	5	2, 2 ?
2724·3	0	1, 0
2713·4	0	

CH

Bands of CH are readily excited during the combustion of hydrocarbons and in electrical discharges where carbon and hydrogen are present. They are also observed in many astrophysical sources. Three systems are known in the regions of 4300 A., 3900 A. and 3143 A. respectively. Their intensities decrease in the order in which they are given, the third usually being much the weakest.

4300 A. System

Occurrence. In sources where carbon and hydrogen are present together such as flames of hydrocarbons, the carbon arc in hydrogen, discharge tubes under a great variety of conditions and in active nitrogen when a hydrocarbon is introduced. It is also observed in emission from the heads of comets and in absorption in the Sun's atmosphere.

Appearance. Usually the 0, 0 band is the only one to appear unless the exposure is very great. This shows a strong broad Q head degraded to the violet and a P branch of open structure which can usually be traced from the Q head to about λ 4384. Both branches consist of narrow doublets. See Plate 4.

Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.

References. C. W. Raffety, *Phil. Mag.*, **32**, 546. (1916)†.
H. Grenat, *C.R. Acad. Sci. Paris*, **192**, 1553. (1931).

	Q Heads			
v′, v″	λ	I	λ	I
0, 1	4890 ?			
0, 0	4312·5	10	4315·0	3

3900 A. System

Occurrence. Similar to the 4300 A. system.

Appearance. The 0, 0 band is of very open structure, degraded to the red. The Q head is rather broad while the R head is sharp and line-like. Other members of the system are obtained a little more readily than in the case of the 4300 A. system. See Plate 4.

Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.

References. As for 4300 A. system.

	Heads			
	Q		R	
v′, v″	λ	I	λ	I
1, 1	4025·3	1		
0, 0	3889·0	4	3872	5
1, 0	3628	1		

3143 A. System

Occurrence. Similar to the above, but favoured by a higher temperature.

Appearance. The 0, 0 and 1, 1 bands have been reported. The branches consist of doublets. The Q branches are at first degraded to the violet, then at the sixteenth member form a second head and turn to the red. This last head is the most intense.

Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.

References. T. Hori, *Z.P.*, **59**, 91. (1930)†.
T. Heimer, *Z.P.*, **78**, 771. (1932).

v′, v″	Q Heads		
1, 1	3156·6		
0, 0	3144·9	3144·1	3143·4

C_2H_2, Acetylene

INFRA-RED ABSORPTION (VIBRATION-ROTATION SPECTRUM)

Reference. K. Hedfeld and R. Mecke, *Z.P.*, **64, 151.** (1930)†.

The vapour shows an absorption band with origin at 7887 A., and maxima of intensity at 7874 and 7901 A. There are also bands, which are presumably weaker, at 7956 and 8622 A.

C_6H_6, Benzene

EMISSION SPECTRUM

Occurrence. The bands are most clearly produced by a Tesla Coil discharge through benzene vapour, but can also be observed in an ordinary uncondensed discharge through flowing benzene vapour.

Appearance. Degraded to the red. Evenly spaced groups of bands similar in general appearance to the sequences of diatomic molecules.

Reference. J. B. Austin and I. A. Black, *P.R.*, **35**, 452. (1934)†.

Austin and Black have published a good photograph and a long list of wavelengths, but no estimates of intensities ; the following are probably the outstanding heads, the intensities being our estimates from the photograph :—

λ	I	λ	I	λ	I	λ	I
2903·7	4	2822·6	4	2751·2	7	2673·5	5
2900·6	3	2820·0	4	2739·1	10	*2667·4	10
*2898·1	4	*2812·3	7	*2736·5	8	2657·5	3
2837·9	6	2810·6	3	2689·2	6	2613·6	8
2832·9	3	2764·9	5	2684·6	6	2608·7	6
2828·1	5	2757·7	4	2678·6	9	*2602·6	9

* Head of group.

ABSORPTION SPECTRUM

Occurrence. Absorption by benzene vapour. The bands are also observed in absorption by liquid benzene and in solution.

Appearance. Degraded to the red. Evenly spaced groups of bands, usually three strong bands to each group. In solution the bands are shifted to the red and are less sharp. See Plate 6.

Reference. V. Henri, *J. de Phys. et le Radium*, **3**, 18. (1922).

The following are the principal heads as observed by Henri for the vapour ; no intensities are recorded and the estimates given below are our own from Henri's description and from the extinction coefficients in solution :—

λ	I	λ	I	λ	I	λ	I
2667·1	1	2539·0		2428·5		*2363·5	3
2602·9		*2528·6	10	2425·3		2324·4	
2599·8		2483·7		*2415·9	5	2313·1	
*2589·0	9	2480·8		2375·2		2275·2	
2541·7		*2471·0	9	2372·5			

* Head of group.

C_6H_6, Benzene (*contd.*)

The following are the approximate wave-lengths of the heads of the strongest groups of absorption bands in various solvents, etc. :—

H_2O	2674	2594	2535	2477	2426	2372
CH_3OH	2682	2605	2543	2484	2430	2375
C_2H_5OH	2684	2606	2545	2485	2433	2377
Hexane	2686	2607	2547	2487	2435	2378
CCl_4	—	2618	2558	2498	2439	—
Liquid benzene	2691	2611	2552	2492	2436	2384
Benzene vapour	2667	2589	2528	2471	2416	2363

Fluorescence Spectrum

Occurrence. Fluorescence of benzene in solution.

Reference. V. Henri (see above).

This system and the emission spectrum and also the absorption spectrum are apparently all parts of the same system, the red end appearing stronger in emission and the shorter wave-length bands in absorption. The fluorescence spectrum is similar to the emission spectrum apart from the shift to longer wave-lengths due to the action of the solvent. The following are the heads as recorded by Henri for solution in pentane :—

λ	I	λ	I
3005	7	2766	10
2917	8	2701	8
2847	9	2659	6

Benzene Derivatives

Most simple derivatives of benzene show a banded absorption spectrum in the region 2600–2400 A. and a Tesla luminescence spectrum of similar type to that of benzene. In addition, McVicker, Marsh and Stewart have observed a system of bands in the blue ; these bands are produced by several benzene derivatives (toluene, ethyl benzene, benzyl alcohol, benzaldehyde, ethyl benzoate), but not by benzene itself or phenol. The emitter of these bands is uncertain, but may be $C_6H_5C\equiv$ or a similar radical.

Occurrence. Tesla coil discharge through benzaldehyde vapour or certain other benzene derivatives.

Reference. W. H. McVicker, J. K. Marsh, A. W. Stewart, *J. Chem. Soc.*, **123**, 2147. (1923)†.

The bands form three strong and one weak group ; they are probably shaded to the red. The following are the approximate wave-lengths of the shorter wave-length edges of the strong bands ; the intensities are our own estimates from the published photograph :—

λ	I	λ	I
4990	?	4255	10
4645	4	4237	5
4600	7	4010	5
4595	3	3970	9
4307	6	3940	3

CHO?

Ethylene Flame Bands

Occurrence. The bands have been observed most strongly in the inner cone of the flame of burning ethylene, but they also occur in the flame of burning ether, benzene, phenol, toluene and many aromatic compounds and weakly in the inner cone of a Bunsen burner.

Appearance. Degraded to the red. Rather diffuse single-headed bands. See Plate 5.

Reference. W. M. Vaidya, *P.R.S.*, **147**, 513. (1934)†.

The bands are attributed to the radical HCO by Vaidya; they have been classed into two systems, A and B, which appear under slightly different experimental conditions; the bands have been arranged into a scheme similar to that for a diatomic molecule. The strong bands of both systems as given by Vaidya are reproduced here :—

System A

λ	I	λ	I	λ	I
4092·0	3	3417·4	3	2797·1	5
3824·9	4	3377·4	10	2751·5	4
3730·5	5	3299·2	10	2716·0	5
3635·6	3	3014·8	8	2658·8	4
3588·6	8	2948·2	7	2618·0	3
3502·7	8	2858·0	6	2585·5	3

System B

λ	I	λ	I
3802·7	2	3359·0	5
3697·7	4	3001·5	2
3569·2	3	2780·4	2
3472·5	5	2704·5	1

CH_2O, Formaldehyde

Absorption Spectrum

Reference. V. Henri and S. A. Schou, *Z.P.*, **49**, 774. (1928)†.

The absorption spectrum of formaldehyde vapour is very complex and not readily identified except by comparison of spectrograms. Henri and Schou give excellent reproductions of the spectrum; the following measurements and intensity estimates are based on these. Some of the bands are degraded to the red, and when there is a definite edge this is given. The wave-length of the strongest line of the structure is also given where available. See Plate 6.

Limits of Strong Part of Band.	Strongest Line.	Edge (Deg. R)	Int.
3456–3418	3430·9	—	2
3416–3377	3389·3	3387	4
3306–3288	3294·7	3288	6
3274–3249	3260·4	—	7
3215–3198	3203·3	3198	3
3185–3164	3170·4	3164	9
3160–3133	3143·4	—	8
3102–3082	3088·7	—	5
—	—	3057	3

CH_2O, Formaldehyde (*contd.*)

Limits of Strong Part of Band.	Strongest Line.	Edge (Deg. R)	Int.
3075–3049	3054·2	3051	5
3048–3028	3035·8	3033 ?	7
2985–2974	2978·9	2978·9	6
2954–2948	2951·9	2948	6
2945–2931	2935·0	2931	10
2898–2874		2874 ?	6
2855–2835		2839	9
2801–2787		2787	7
2766–2756		2756	5
2756–2747		2747	5
2716–2706		—	3
2675–2667		2667	1

Fluorescence Spectrum

Reference. G. Herzberg and K. Franz, *Z.P.*, **76**, 720. (1932).

The following are the wave-lengths of the maxima of the strong bands in the fluorescence spectrum of formaldehyde vapour; intensities are our estimates from Herzberg and Franz's diagram :—

λ	I	λ	I	λ	I	λ	I
5107	1	4566·8	6	4129·2	9	3855·5	8
4942	1	4447·6	6	4053·3	7	3767	1
4821	2	4359·9	7	3959·6	10	3706·3	4
4707·1	3	4242·8	9				

C_2H_4O, Acetaldehyde

Occurrence. Absorption by acetaldehyde vapour.

Appearance. Strong absorption with maximum at 2900 A., with a complex structure of discrete bands from 3400 A. to 3200 A., after which they become diffuse and finally merge into continuum around 2800 A. Some of the bands appear to be shaded to the red.

Reference. S. A. Schou, *Jour. de Chim. Phys.*, **26**, 27. (1929).

The following are the limits of the outstanding bands as taken from Schou's list :—

λ	I	λ	I	λ	I	λ	I
3399·3 3381·1	3	3320·0 3314·7	6	3254·4 3247·3	6	3207·3 3202·0	6
3376·6 3363·0	2	3305·1 3299·9	4	3241·1 3234·1	6	3199·0 3196·1	7
3359·0 3344·5	4	3296·2 3289·9	6	3231·4 3228·7	5	3190·9 3180·2	9
3341·7 3328·9	3	3281·3 3274·4	5	3222·1 3216·9	5	3177·5 3172·2	8
		3267·6 3258·3	7	3215·6 3212·7	6	Diffuse bands extend to 2800, after which absorption is continuous.	

C_2H_5CHO, Propionaldehyde

Occurrence. Absorption by the vapour.

Appearance. Complex system of diffuse bands from 3400 A., merging into a continuum at 3250 A., this continuum extending to about 2500 A.

Reference. S. A. Schou, *Jour. de Chim. Phys.*, **26**, 39. (1929).

The following are the limits of the strongest bands :—

λ	I	λ	I	λ	I
3370·8	4	3322·0	8	3276·7	8
3363·9		3316·4		3272·3	
3343·6	5	3298·1	9	3269·0	7
3339·6		3294·2		3262·0	
3336·1	6	3288·7	8	3258·7	8
3332·3		3284·8		3248·9	
3331·4	6				
3324·9					

C_3H_6O, Acetone

Occurrence. Absorption by the vapour.

Reference. E. J. Bowen and H. W. Thompson, *Nature*, **133**, 571. (1934).

Acetone shows continuous absorption from 3200 A. to 2400 A., with a maximum at about 2800 A. At low pressure this continuum breaks up into four groups each of about 25 diffuse bands ; these groups have maxima at 3150, 2900, 2710 and 2570 A.

C_6H_5CHO, Benzaldehyde

Occurrence. Absorption by benzaldehyde vapour.

Reference. M. Hemptinne, *J. Phys. Radium*, **9**, 357. (1928)†.

The following maxima of the narrow headless bands are taken from Hemptinne's published spectrogram. Intensities (on a scale of 5) are our estimates from the spectrogram, and some of the wave-lengths are also taken from this.

λ	I	λ	I	λ	I
2851	1	2766*	4	2716	1
2841	5	2746	3	2709	2
2806	2	2735	3	2696	2
2777	2	2726	1	2677	2

* A misprint in the wave-length recorded has been corrected.

CH_3NO_2, Methyl Nitrite

Occurrence. Absorption by vapour.

Appearance. Diffuse bands in near ultra-violet, and continuous absorption further in ultra-violet.

References. H. W. Thompson and C. H. Purkis, *Trans. Faraday Soc.*, **32**, pp. 674 and 1466. (1936)†.

Strongest bands, with our estimates of intensity from published photograph in brackets :—

λλ3651 (4), 3508 (9), 3390·2 (10), 3284·1 (8), 3187·1(5)

$C_2H_5NO_2$, Ethyl nitrite

Occurrence. Absorption by vapour.

Appearance. Diffuse bands in near ultra-violet and continuous absorption in further ultra-violet.

References. See methyl nitrite.

Strong bands, with own estimates of intensities from published photograph given in brackets :—

λλ3689 (4), 3549 (10), 3429 (8), 3316 (4), 3221 (2).

CN

There are two systems of bands due to CN known as the cyanogen red and violet systems. They are both easily excited and are frequently encountered as impurities in many types of spectra.

Red System

Occurrence. In the carbon arc in air, in the flame of burning cyanogen, in discharge tubes containing nitrogen and carbon compounds, and especially strongly when vapours such as C_2H_2 and $HCCl_3$ are introduced into active nitrogen.

Appearance. Degraded to red. Triple-headed bands roughly equally spaced. See Plate 5.

Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. A. Fowler and H. Shaw, *P.R.S.*, **86**, 118 (1911)†.
F. A. Jenkins, *P.R.*, **39**, 16 (1932).
R. K. Asundi and J. W. Ryde, *Nature*, **124**, 57 (1929).

The following table is compiled from the above references. The bands in the infra-red are by Asundi and Ryde ; only the R_2 heads of these are given and no intensities are available. Most of the other bands are from Fowler and Shaw, with the wave-lengths reduced by 0·6 A to bring them into line with Jenkin's measurements. Intensities I_f, I_v, and I_n refer to cyanogen flame, vacuum tube, and active nitrogen. In all cases the R_2, R_1, and Q_1 heads are of about equal strength, the central R_1 head being perhaps a little the stronger. The $^sR_{21}$ heads, where observed, are much weaker.

λ	I_f	I_v	I_n	v′, v″		λ	I_f	I_v	I_n	v′, v″	
9393				1, 1	R_2	6954·3	2	2	1	2, 0	Q_1
9140·5				0, 0	R_2	6945·4					R_1
8708				5, 4	R_2	6927·6					R_2
8485				4, 3	R_2	6817·6	0	2	3	7, 4	Q_1
8272				3, 2	R_2	6809·2					R_1
8067				2, 1	R_2	6792·5					R_2
7874				1, 0	R_2	6779·6					$^sR_{21}$
7435				5, 3	R_2	6656·6	4	9	7	6, 3	Q_1
7283				4, 2	Q_1	6648·1					R_1
7273					R_1	6631·6					R_2
7259					R_2	6620·8					$^sR_{21}$
7119				3, 1	Q_1	6502·3	9	10	10	5, 2	Q_1
7110					R_1	6494·1					R_1
7091					R_2	6478·7					R_2
6961·0		1	1	8, 5	R_2	6466·7					$^sR_{21}$

CN (*contd.*)

λ	I_f	I_v	I_n	v', v''	
6456·4		1	1	10, 6	Q_1
6448·3					R_1
6432·7					R_2
6355·1	10	9	6	4, 1	Q_1
6347·0					R_1
6332·2					R_2
6301·2		1	2	9, 5	Q_1
6293·7					R_1
6279·4					R_2
6271·9					$^sR_{21}$
6213·8	6	4	1	3, 0	Q_1
6206·1					R_1
6191·7					R_2
6153·5	0	3	3	8, 4	Q_1
6146·8					R_1
6133·0					R_2
6123·8					$^sR_{21}$
6012·5	2	6	6	7, 3	Q_1
6006·0					R_1
5992·6					R_2
5984·3					$^sR_{21}$
5877·6	2	9	9	6, 2	Q_1
5871·3					R_1
5858·2					R_2
5849·3					$^sR_{21}$
5748·7	5	7	7	5, 1	Q_1
5742·7					R_1
5730·2					R_2
5721·8					$^sR_{21}$
5728·5		1	1	10, 5	R_2
5625·0		2	2	4, 0	Q_1
5618·8					R_1
5606·7					R_2
5615·7	3	3	4	9, 4	Q_1
5610·5					R_1
5598·3					R_2
5590·6					$^sR_{21}$
5490·2	2	5	5	8, 3	Q_1
5484·9					R_1
5473·3					R_2
5466·6					$^sR_{21}$
5365·0	2	4	6	7, 2	Q_1
5354·1					R_1
5347·5					R_2
5254·9	2	3	5	6, 1	Q_1
5250·0					R_1
5239·3					R_2
5232·6					$^sR_{21}$
5155·7			1	10, 4	R_2
5129·7		1	1	5, 0	R_2
5043·1		1	1	9, 3	R_2
4949·1	1	2	3	8, 2	Q_1
4945·3					R_1
4835·8					R_2
4930·7					$^sR_{21}$
4845·3	1	?	4	7, 1	Q_1
4841·7					R_1
4832·6					R_2
4827·7					$^sR_{21}$
4784·9			1	11, 4	R_2
4732·7			2	6, 0	R_2
4682·0			2	10, 3	R_2
4488·8			0	8, 1	R_2
4373·8			0	11, 3	R_2

VIOLET SYSTEM

Occurrence. In carbon arc in air, in discharge tubes containing nitrogen and carbon compounds, and when carbon compounds are introduced into active nitrogen. These bands occur very frequently as impurities in discharge tube sources, and in arcs between carbon poles.

Appearance. In arc sources three strong sequences with heads at λ4216, 3883, and 3590 degraded to the violet. In active nitrogen the heads of the 4216 and 3590 sequences are less marked, and "tail" bands are observed; these are degraded to the red. See Plate 5.

Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

References. Main system. W. Jevons, *P.R.S.*, **112**, 407. (1926)†.
Tail bands. F. A. Jenkins, *P.R.*, **31**, 539. (1928)†.

Main System. Intensities I_c and I_n are for carbon arc and active nitrogen respec-

CN (*contd.*)

tively. The values of I_c are our own estimates from Jevons's plates. The values of I_n are from Jenkins, reduced to a scale of 10. Degraded to violet.

λ	I_c	I_n	v′, v″	λ	I_c	I_n	v′, v″
4606·1	1	0	0, 2	4158·1	5	4	4, 5
4578·0	2	0	1, 3	4152·4	4		5, 6
4553·1	2	0	2, 4	3883·4	10	10	0, 0
4531·9	2	0	3, 5	3871·4	9	4	1, 1
4514·8	2	1	4, 6	3861·9	8	4	2, 2
4502·2	2	1	5, 7	3854·7	6	5	3, 3
4216·0	9	2	0, 1	3590·4	8		1, 0
4197·2	8	4	1, 2	3585·9	7		2, 1
4181·0	7	4	2, 3	3583·9	6		3, 2
4167·8	6	3	3, 4				

Tail Bands. Wave-lengths λ_h and λ_o are for the heads and the origins of the bands respectively. Intensities are for active nitrogen and are on a scale of 40 for the (0, 0) band at 3883. Degraded to the red.

λ_h	λ_o	I	v′, v″	λ_h	λ_o	I	v′, v″
4078·7	4083·2	1	15, 15	3658·1	3665·3	2	11, 10
4029·3	4034·6	3	14, 14	3628·9	3638·4	4	10, 9
3984·6	3991·1	5	13, 13	3603·0	3616·6	9	9, 8
3944·7	3953·3	8	12, 12	3501·4	3504·8	0	13, 11
3909·5	3920·8	9	11, 11		3469·1	0	12, 10
	3894·1	10	10, 10	3433·0	3437·8	0	11, 9
	3697·1	0	12, 11				

C_2N_2, Cyanogen

Two systems of absorption bands have been observed for cyanogen gas. The stronger lies below 2300 A. and the weaker system which appears with absorption through 1½ metres of gas at atmospheric pressure is in the region 3100–2400 A.

References. Sho-Chow Woo and R. M. Badger, *P.R.*, **39**, 932. (1932).
Soo-Choo Woo and Ta-Kong Liu, *J. Chem. Phys.*, **5**, 161. (1937).

Strong bands of main system as observed by Sho-Chow Woo and Badger; most of the bands are shaded to longer wave-lengths.

λ	I	λ	I	λ	I
2237·7	3	2164·5	4	2107·4	7
2226·4	5	2145·6	4	2093·1	10
2200·0	5	2137·7	4	2054·6	7
2188·2	9	2125·0	7	2035·2	7
				2007·0	10

Strongest bands of weak system as observed by Soo-Choo Woo and Ta-Kong Liu; narrow bands degraded to the red.

λ	I	λ	I	λ	I
3002·7	3	2759·2	3	2614·0	4
2831·1	3	2678·5	4	2540·3	5
2828·6	5	2675·6	6	2508	7

CO

More band systems are known for CO than for any other molecule. The electronic levels involved are singlet and triplet. Some of the systems are very frequently obtained as impurities in the spectra from discharge tubes. The bands most commonly encountered are the Angstrom bands in the visible, the Third Positive system in the near ultra-violet and the Fourth Positive system in the far ultra-violet and vacuum regions. A trace of CO in one of the rare gases often gives the Triplet system.

The Angstrom System

Occurrence. Readily obtained with CO or CO_2 in the positive column of an uncondensed discharge. The glass of a new discharge tube usually produces enough CO to give these bands and those of the Third Positive system.

Appearance. A progression of bands with strong single heads degraded to the violet. See Plate 2.

Transition. $B\,^1\Sigma \rightarrow A\,^1\Pi$.

References. R. C. Johnson and R. K. Asundi, *P.R.S.*, **123**, 560. (1929).
E. Hulthén, *Ann. Physik*, **71**, 41. (1923).
O. Jasse, *C.R., Acad. Sci., Paris*, **182**, 692. (1926).

The following are the heads usually observed :—

λ	I	v′, v″	λ	I	v′, v″
6620·3	7	0, 5	5198·2	10	0, 2
6299	2	1, 6	5016	1	1, 3
6079·9	9	0, 4	4835·3	10	0, 1
5818	2	1, 5	4510·9	10	0, 0
5610·2	10	0, 3	4393·1	8	1, 1
5399	2	1, 4	4123·6	7	1, 0

The Herzberg System

Occurrence. From CO in discharge tubes and controlled electron sources with conditions favourable for the production of the Angstrom bands.

Appearance. The bands are degraded to the violet and are very similar in appearance to the Angstrom bands.

Transition. $C\,^1\Sigma \rightarrow A\,^1\Pi$.

References. O. S. Duffendack and G. W. Fox, *Astrophys. J.*, **65**, 214. (1927).
R. C. Johnson and R. K. Asundi, *P.R.S.*, **123**, 560. (1929).
G. Herzberg, *Z.P.*, **52**, 815. (1929).

	I	v′, v″		I	v′, v″
5705·9	1	0, 7	4380·3	7	0, 3
5318·4	1	0, 6	4124·8	7	0, 2
4972·8	2	0, 5	3893·1	7	0, 1
4661·3	5	0, 4	3680·9	4	0, 0

Fourth Positive System

Occurrence. In the positive column of discharge tubes containing carbon monoxide

CO (*contd.*)

or carbon dioxide ; the system appears very readily. The shorter wave-length end of the system can also be obtained in absorption.

Appearance. Degraded to the red. An extensive system of apparently single-headed bands extending from 2800 A. to 1000 A. See Plate 2.

Transition. A $^1\Pi \rightarrow$ X $^1\Sigma$, ground state.

References. R. S. Estey, *P.R.*, **35,** 309. (1930).
L. B. Headrick and G. W. Fox, *P.R.*, **35,** 1033. (1930)†.
D. N. Read, *P.R.*, **46,** 571. (1934).

The following measurements of the bands of wave-length greater than 2000 A are by Estey ; these values are about $\frac{1}{2}$ A. smaller than the measurements by Read or Headrick and Fox, whose measurements are, however, chiefly concerned with the shorter wave-length end of the spectrum.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2799·7	9 ?	9, 22	2492·9	8	10, 20	2247·2	7	8, 16
2785·4	8 ?	4, 18	2483·8	3	6, 17	2238·3	9	4, 13
2742·6	6	11, 23	2463·2	10	9, 19	2221·5	10	7, 15
2740·0	4	7, 20	2458·0	2	5, 16	2215·8	3	3, 12
2712·1	4	6, 19	2433·9	9	8, 18	2196·8	10	6, 14
2698·3	6	13, 24	2424·1	5	11, 20	2173·0	9	5, 13
2684·0	3	5, 18	2407·6	7	7, 17	2150·2	8	4, 12
2680·8	5	9, 21	2394·2	3	10, 19	2137·0	5	7, 14
2662·9	4	12, 23	2393·1	4	13, 21	2128·3	8	3, 11
2661·5	4	15, 25	2381·6	6	6, 16	2113·1	9	6, 13
2659·6	4	4, 17	2365·5	5	9, 18	2107·2	7	2, 10
2630·0	6	11, 22	2356·5	4	5, 15	2089·9	10	5, 12
2598·3	4	10, 21	2337·9	7	8, 17	2086·9	1	1, 9
2594·5	1	16, 25	2332·5	3	4, 14	2067·6	10	4, 11
2567·8	5	9, 20	2311·5	8	7, 16	2046·3	10	3, 10
2556·0	3	12, 22	2286·1	7	6, 15	2025·8	9	2, 9
2538·6	4	8, 19	2273·9	3	9, 17	2011·8	8	5, 11
2521·8	3	14, 23	2272·3	1	12, 19	2005·8	5	1, 8
2509·9	8	7, 18	2261·7	9	5, 14			

The Third Positive and 5B Bands

These bands fall into two progressions which at one time were thought to belong to two different systems. Some papers therefore refer to one progression as the Third Positive Bands and the other as the 5B Bands ; other papers refer to all the bands as the Third Positive System.

Occurrence. With CO in discharge tubes under a wide range of conditions. A mere trace of CO gives the bands strongly in the positive column with an uncondensed discharge.

Appearance. A progression of five strong bands with five close subheads, forming the Third Positive group, consisting of the strongest members of the $(0, v'')$ progression, and a weaker progression of bands of a similar type forming the 5B group. Degraded to the violet. See Plate 2.

Transition. $b\ ^3\Sigma \rightarrow a\ ^3\Pi$.

CO (*contd.*)

References. G. H. Dieke and J. W. Mauchly, *P.R.*, **43**, 12. (1933).
O. S. Duffendack and G. W. Fox, *Astrophys. J.*, **65**, 214. (1927).
B. S. Beer, *Z.P.*, **107**, 73. (1937).

3rd. Pos.

λ	I	v′, v″
2833·1	10	0, 0
2977·4	9	0, 1
3134·4	8	0, 2
3305·7	7	0, 3
3493·3	6	0, 4
3699	2	0, 5

5B.

λ	I	v′, v″
2665·3	8	1, 0
2793·1	2	1, 1
2930	1	1, 2
3079·9	5	1, 3
3242·1	6	1, 4
3419·2	5	1, 5
3612·7	5	1, 6
3825·1	2	1, 7

THE ASUNDI BANDS

Occurrence. In the positive column of a discharge tube containing CO.
Appearance. Bands degraded to the red with complex structure ; probably containing five heads.
Transition. $a'\ {}^3\Sigma \rightarrow a\ {}^3\Pi$.
References. R. K. Asundi, *P.R.S.*, **124**, 277. (1929).
L. Gerö and K. Lorinczi, *Z.P.*, **113**, 449. (1939).

The following measures are by Asundi who used small dispersion and measured only two extreme heads for each band.

λ	I	v′, v″
8592	2	1, 0
8222·5	1	3, 1
7833·9	3	2, 0
7552·5	1	4, 1
7314·0	2	6, 2
7210·4	5	3, 0
7116·5	3	8, 3
6990·2	2	5, 1

λ	I	v′, v″
6804·0	8	7, 2
6685·7	7	4, 0
6513·5	9	6, 1
6366·9	5	8, 2
6244·0	5	5, 0
6105·2	5	7, 1
5861·0	6	6, 0
5749·1	6	8, 1

According to Gerö and Lorinczi the values of v′ given by Asundi should be increased by three units.

THE TRIPLET BANDS

Occurrence. Obtained by Merton and Johnson in a wide-bore discharge tube containing helium and hydrogen with a trace of CO with an uncondensed discharge.
Appearance. With moderate dispersion the bands, which are degraded to the red, show a well-marked triple structure.
Transition. $d\ {}^3\Pi \rightarrow a\ {}^3\Pi$.
References. T. R. Merton and R. C. Johnson, *P.R.S.*, **103**, 383. (1923)†.
L. Gerö and F. Szabó, *Ann. Physik.*, **35**, 597. (1939).

CO (*contd.*)

The following are the wave-lengths and intensities given by Merton and Johnson :—

λ	I	λ	I	λ	I
6464·6		5428·3		4949·8	
6433·1	10	5414·5	1	4935·5	2
6403·8		5402·5		4920·0	
6399·0				4917·1	
		5351·3			
6383·1		5330·5	5	4823·5	
6348·7	1	5309·5		4806·7	8
6319·8		5307·2		4787·3	
6037·0		5258·3		4764·8	
6010·5	8	5238·4	5	4747·5	5
5980·7		5215·3		4729·1	
5836·9		5140·3		4602·6	
5812·1	2	5128·1	2	4586·4	7
5780·9		5116·2		4572·2	
5777·1				4569·2	
		5070·9			
5670·5		5052·7	8	4556·8	
5647·6	6	5033·8		4541·3	5
5626·0		5031·7		4526·2	
5621·7				4524·7	
		4996·9			
5554·1		4979·0	6	4454·5	
5532·5	5	4960·5		4445·5	1
5509·7		4958·2		4438·0	
5507·1				4436·4	

THE CAMERON BANDS

Occurrence. Cameron obtained these bands in a wide-bore discharge tube filled with neon using an uncondensed discharge but with low intensity. Hansche using a continuous-wave oscillator to excite CO in a 12-litre flask finds that the Cameron bands reach a maximum intensity at a pressure between 0·003–0·002 mm. of Hg. May also be obtained in absorption.

Appearance. Degraded to the red. Five close heads to each band.

Transition. $a\ {}^3\Pi \rightarrow X\ {}^1\Sigma$. Intercombination to ground state.

References. W. H. B. Cameron, *Phil. Mag.*, **1**, 405. (1926).
G. Herzberg, *Z.P.*, **52**, 815. (1929).
L. Gerö, G. Herzberg and R. Schmid, *P.R.*, **52**, 467. (1937).
G. E. Hansche, *P.R.*, **57**, 289. (1940).

The following are Cameron's wave-lengths for the furthest ultra-violet head of each band. The data for the 0, 0 and 1, 0 bands are added from the paper by Gerö, Herzberg and Schmid.

CO (*contd.*)

λ	I	v′, v″	λ	I	v′, v″
2575·3	8	4, 8	2409·2	7	2, 5
2553·3	6	3, 7	2388·8	7	1, 4
2531·9	4	2, 6	2369·0	3	0, 3
2510·9	6	1, 5	2277·0	1	1, 3
2492·9*	4	0, 4	2257·7	1	0, 2
2451·8	6	4, 7	2059·6		0, 0
2430·3	3	3, 6	1989·4		1, 0

* Second head; first missing.

THE 3A BANDS

Occurrence. In discharge tube containing CO. Schmid and Gerö obtained them with high intensity in a discharge tube containing neon with carbon electrodes.
Appearance. Degraded to the violet with five heads close together. Under low dispersion appear double-headed.
Transition. $c\ {}^3\Sigma \rightarrow a\ {}^3\Pi$.
References. R. Schmid and L. Gerö, *Nature*, **139**, 928. (1937).
R. K. Asundi, *P.R.S.*, **124**, 277. (1929).
L. Gerö, *Z.P.*, **109**, 210. (1938).

λ	I	v′, v″
2711·3	3	0, 4
2596·9	4	0, 3
2489·9	5	0, 2
2389·7	5	0, 1
2295·9	4	0, 0

OTHER BANDS OF CO

Knauss Bands. Four bands were obtained in an electrodeless discharge through CO. The bands were degraded to the violet and assigned to the transition $C\ {}^1\Sigma \rightarrow a\ {}^3\Sigma$.
Reference. H. P. Knauss and J. C. Cotton, *P.R.*, **36**, 1099. (1930).
The approximate wave-lengths are :—

λ	v′, v″
3253	0, 3
3138	0, 2
3028	0, 1
2925	0, 0

Kaplan Bands. (1) Three bands were obtained in a long atomic hydrogen tube. Each band apparently contained six heads degraded to the violet and resembled the bands of the Third Positive and 3A systems. Wave-lengths given by Kaplan were 2750 A., 2630 A., 2518 A.
Reference. J. Kaplan, *P.R.*, **35**, 1298. (1930).

(2) An intense band at 2575 A., degraded to the red, was obtained in quenching mercury-resonance radiation by CO. This coincides in position with the (0, 0) band of CS.
Reference. J. Kaplan, *P.R.*, **36**, 788. (1930).

CO^+

There are three band systems attributed to ionised carbon monoxide, the First Negative Carbon bands, the Comet-tail bands, and the Baldet-Johnson system.

First Negative System

Occurrence. In the cathode glow of discharge tubes containing CO or CO_2, especially in hollow cathode. Also in discharges through helium containing a trace of CO. These bands like most systems of CO are very frequent impurities in discharge tubes, especially at low pressures. They also occur in an electron beam.

Appearance. Degraded to red. Single-headed bands forming fairly obvious sequences. See Plate 2.

Transition. $B^2\Sigma \rightarrow {}^2\Sigma$, ground state of ionised CO.

References. R. C. Johnson, *P.R.S.*, **108, 343.** (1925)†.
H. Biskamp, *Z.P.*, **86,** 33. (1933).

The following values are from Biskamp's measurements. A few weak bands below 2000 A. are omitted.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3152·7	1	8, 13	2607·2	8	2, 5	2220·3	0	8, 6
3107·5	2	7, 12	2577·7	10	1, 4	2214·5	5	1, 1
3064·0	3	6, 11	2550·3	7	0, 3	2189·8	10	0, 0
3023·0	2	5, 10	2530·8	1	4, 6	2185·1	4	7, 5
2984·2	2	4, 9 8, 12	2504·6	10	3, 5	2164·3	5	3, 2
2947·6	1	3, 8	2474·2	10	2, 4	2154·1	4	6, 4
2938·5	1	7, 11	2445·8	10	1, 3	2137·8	6	2, 1
2913·2	1	2, 7	2419·4	8	0, 2	2123·8	3	5, 3
2897·2	3	6, 10	2412·4	4	4, 5	2112·4	8	1, 0
2882·2	2	1, 6	2381·5	5	3, 4	2095·3	5	4, 2
2874·5	0	9, 12	2362·5	1	6, 6	2091·0	4	7, 4
2858·1	4	5, 9	2352·5	6	2, 3	2067·9	1	3, 1
2820·8	5	4, 8	2325·2	9	1, 2	2067·8	1	9, 5
2785·8	5	3, 7	2299·6	10	0, 1	2061·0	3	6, 3
2752·9	6	2, 6	2298·2	3	4, 4	2042·3	4	2, 0
2745·1	1	6, 9	2293·7	1	10, 8	2034·3	2	8, 4
2722·3	7	1, 5	2268·6	3	3, 3	2032·3	1	5, 2
2707·9	3	5, 8	2255·7	1	9, 7	2004·7	0	4, 1
2693·9	2	0, 4	2254·3	2	6, 5	2003·1	0	7, 3
2672·4	7	4, 7	2240·4	4	2, 2			
2638·8	8	3, 6	2222·7	4	5, 4			

Comet-tail System

Occurrence. In discharge tubes containing CO or CO_2 at relatively very low pressure, in electron beam through CO at low pressure, in discharge tubes containing helium with a trace of CO, and in the tails of comets.

Appearance. Degraded to red. Double-headed bands.

Transition. $A\,^2\Pi \rightarrow {}^2\Sigma$, ground state of ionised CO.

References. M. F. Baldet, *C.R. Acad. Sci. Paris*, **180,** 271. (1925).
M. F. Baldet, *C.R. Acad. Sci. Paris*, **180,** 820. (1925).
T. R. Merton and R. C. Johnson, *P.R.S.*, **103,** 383. (1923)†.

CO^+ (*contd.*)

R. C. Johnson, *P.R.S.*, **108**, 343. (1925).
D. Coster, H. H. Brons and H. Bulthuis, *Z.P.*, **79**, 787. (1932).

The measurements and intensities as listed below are average values compiled from the above references ; the list given by Baldet is the most complete. Except for the two strongest bands only the two R heads are given here. The corresponding Q heads lie from 5 (for bands in the red) to 1·5 A. to the red of the R heads. The Q heads are rather stronger than the R heads, but are usually masked by the overlapping lines of the R branch. The R_2 head is always a little stronger than the R_1 head.

λ	I	v′, v″
6405	0	0, 0 R_2
6354		R_1
6238·7	7	3, 2 R_2
6189·4		R_1
6015	0	2, 1 R_2
5970		R_1
5900·4	1	5, 3 R_2
5856·5		R_1
5806	0	1, 0 R_2
5764		R_1
5693·6	3	4, 2 R_2
5652·6		R_1
5499·9	6	3, 1 R_2
5461·4		R_1
5072·1	5	4, 1 R_2
5039·7		R_1
4910·9	3	3, 0 R_2
4879·5		R_1
4865·8	1	6, 2 R_2
4836·6		R_1
4711·2	5	5, 1 R_2
4683·4		R_1

λ	I	v′, v″
4565·8	8	4, 0 R_2
4539·4		R_1
4518·0	3	7, 2 R_1
4403·3	2	6, 1 R_2
4378·9		R_1
4274·3	10	5, 0 Q_2
4272·0		R_2
4252·4		Q_1
4248·9		R_1
4244·1	1	8, 2 R_1
4151·9	1	10, 3 R_2
4130·4		R_1
4138·9	2	7, 1 R_2
4117·3		R_1
4019·7	9	6, 0 Q_2
4017·7		R_2
3999·6		Q_1
3997·3		R_1
3908·0	2	8, 1 R_2
3888·6		R_1
3795·8	8	7, 0 R_2
3777·8		R_1

λ	λ	v′, v″
3705·3	4	9, 1 R_2
3688·1		R_1
3600·8	6	8, 0 R_2
3584·2		R_1
3525·6	2	10, 1 R_2
3510·3		R_1
3427·9	4	9, 0 R_2
3413·3		R_1
3366·1	2	11, 1 R_2
3351·7		R_1
3314·2	1	13, 2 R_2
3300·7		R_1
3273·9	2	10, 0 R_2
3260·4		R_1
3222·4	1	12, 1 R_2
3209·7		R_1
3180·3	1	14, 2 R_2
3168·1		R_1
3135·5	1	11, 0 R_2
3123·2		R_1
3093·3	0	13, 1 R_2
3081·5		R_1

Baldet-Johnson System

Occurrence. In discharge through helium containing a trace of CO, and in electron beam through CO at low pressure. This is an intercombination system between the initial levels of the First Negative and the Comet-tail systems and occurs under similar conditions.

Appearance. Degraded to shorter wave-lengths. Double double-headed bands.

Transition. $B\ {}^2\Sigma \rightarrow A\ {}^2\Pi$, initial state of Comet-tail bands.

References. R. C. Johnson, *P.R.S.*, **108**, 343. (1925)†.
M. F. Baldet, *C.R. Acad. Sci. Paris*, **178**, 1525. (1924).

CO^+ (*contd.*)

The measurements and intensities listed below are averaged values from the above references :—

λ	I	v′, v″	λ	I	v′, v″
4236·2	3	0, 1 P_1	3729·7	3	1, 0 P_1
4231·6	8	Q_1	3724·9	8	Q_1
4212·9	7	P_2	3711·2	9	P_2
4209·1	8	Q_2	3707·4	9	Q_2
—			3515·8	2	2, 0 P_1
4201·5	1	1, 2 Q_1	3511·7	7	Q_1
4182·6	1	P_2	3500·4	3	P_2
4179·1	1	Q_2	3496·7	4	Q_2
3977·7		40, 0 P_1	3331·9	1	3, 0 P_1
3973·5	9	Q_1	3329·0	1	Q_1
3957·0	7	P_2	3317·9	1	P_2
3953·6	10	Q_2	3314·8	1	Q_2

CO_2 and CO_2^+

Two extensive band systems are believed to be due to the neutral CO_2 molecule ; the first has been studied extensively by Fox, Duffendack and Barker, and the second occurs in the flame of burning carbon monoxide. Two very strong persistent bands at about 2883 and 2896 A. are probably due to the ionised molecule CO_2^+.

Fox, Duffendack and Barker's System

Occurrence. In the negative glow of discharges through streaming carbon dioxide ; the bands appear strongly in a hollow cathode and have also been produced with a trace of carbon dioxide in the presence of helium or neon. The bands have been observed as an impurity in the spectrum of what was thought to be pure oxygen. The spectrum has been studied most completely when excited by a beam of electrons through streaming carbon dioxide at low pressure ; as observed in this way the bands are fairly free from the many systems due to CO.

Appearance. Narrow bands degraded to the red. The system extends from 2800 to nearly 5000 A. At the ultra-violet end the appearance is relatively simple, the bands forming marked groups which resemble sequences, but the longer wave-length end is very confused and presents few definite features. See Plate 2.

Reference. H. D. Smyth, *P.R.*, **38**, 2000. (1931)†.

There are several earlier papers by Fox, Duffendack and Barker and colleagues, and R. Schmid has more recently made good progress with the rotational analysis.

The following measurements are by Fox, Duffendack and Barker (after Smyth) and the intensities are by Smyth for electron beam excitation. Only the strong bands are reproduced here. Bands marked with an asterisk are at the head of characteristic groups which are prominent in the spectrum as obtained from discharge tubes.

CO_2 and CO_2^+ (*contd.*)

λ	I	λ	I	λ	I	λ	I
4159·5	5	3761·4	4	3400·9	5	3155·2	5
4137·6	6	3691·8	6	3394·5	4	3149·5	4
4120·8	6	3674·1	5	3388·9	4	3139·2	5
4107·9	5	*3661·6	5	3377·5	8	3136·7	5
4070·7	5	3621·0	7	*3370·0	8	3134·6	4
4048·9	5	3565·5	5	3284·3	3	*3132·9	4
3960·9	7	3562·2	6	3269·9	5	3063·5	4
3890·4	4	3551·4	6	3264·6	5	3058·3	4
3870·5	7	3545·9	7	3253·9	6	3048·6	5
3853·2	4	3533·8	4	*3246·9	6	3034·2	4
3838·8	6	3510·8	3	3164·9	3	2874·3	5
3774·6	4	*3503·2	3				

Carbon Monoxide Flame Spectrum

Occurrence. In flame of carbon monoxide burning in air or oxygen. The bands have also been observed in the afterglow of a heavy current discharge through carbon dioxide.

Appearance. A great number of narrow bands, not clearly degraded in either direction, on a continuous background. The bands are strongest between 5000 A. and 3500 A., with maximum intensity around 4200 A., but the system can be extended from the green to beyond the OH band at 3064 A. with long exposure. The bands are favoured, relatively to the continuous background, by low pressure. See Plate 5.

References. F. R. Weston, *P.R.S.*, **109**, 176. (1925)†.
A. Fowler and A. G. Gaydon, *P.R.S.*, **142**, 362. (1933)†.
A. G. Gaydon, *P.R.S.*, **176**, 505. (1940)†.

This complex system is best identified by direct comparison of photographs, but the following measurements (from Weston) of the maxima of the strongest bands may be of assistance. λλ5430, 5318, 5278, 5169, 5129, 5026, 4981, 4932, 4896, 4798, 4769, 4659, 4654, 4577, 4557, 4528, 4485, 4413, 4344, 4260, 4154, 3911.

Bands λλ2883 and 2896

Occurrence. These bands are very persistent and occur in almost all discharge tubes containing carbon dioxide or even carbon monoxide. They are favoured by freshly streaming gas and relatively energetic excitation, *i.e.*, negative glow or hollow cathode. They are of frequent occurrence as an impurity.

Appearance. Two strong narrow bands of almost line-like sharpness, each being a close doublet; intensity maxima at about λλ2897·5, 2895·1, 2884·0 and 2881·8. There are also weaker heads at λλ2890·5, 2877·5 and 2874·8. See Plate 2.

Reference. R. Schmid, *Z.P.*, **83**, 711. (1933)†.

C_3O_2

Occurrence. In absorption by carbon suboxide vapour.

Appearance. Narrow diffuse bands, evenly spaced in the region 3380–3250 A. and occurring in pairs on a complex banded background in the region 3250–2910 A.

Reference. H. W. Thompson and N. Healey, *P.R.S.*, **157**, 331. (1936).

C_3O_2 (*contd.*)

The following are the maxima of the strong bands, λλ3350, 3332, 3316, 3302, 3292, 3277, 3251, 3175, 3166, 3136, 3127, 3092, 3082, 3047, 3038, 3015, 3006, 2994, 2987, 2955 and 2946.

COS?

Emission

Occurrence. Discharge through flowing carbonyl sulphide vapour.

Appearance. Degraded to shorter wave-lengths. A regularly spaced group of bands.

Reference. A. Fowler and W. M. Vaidya, *P.R.S.*, **132,** 310. (1931).

Bands λλ3077, 3043, 3009, 2976 ?, 2943, 2911 and 2880.

Absorption

Reference. W. Lochte-Holtgreven and C. E. H. Bawn, *Trans. Faraday Soc.*, **28,** 698. (1932).

Absorption band extending from a sharp edge at 2550 ± 20 A. towards shorter wave-lengths.

CP

Two systems, with the same initial level, are known.

Occurrence. In discharge tubes containing argon, phosphorus and an organic vapour.

Reference. H. Barwald, G. Herzberg and L. Herzberg, *Ann. Physik,* **20,** 569. (1934)†.

System A, near Ultra-violet

Appearance. Degraded to red. Single-headed bands.

Transition. $B\,^2\Sigma \rightarrow X\,^2\Sigma$, probably ground state.

The following are the strong bands. Intensities have been increased to a scale of 10.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4014·8	8	1, 4	3459·2	10	0, 0	3190·2	8	3, 0
3957·1	6	0, 3	3363·5	10	1, 0	3111·8	6	4, 0
3777·9	8	0, 2	3320·1	6	3, 1	3038·6	5	5, 0
3612·4	10	0, 1	3273·7	6	2, 0	3054·8	6	8, 2
3508·2	8	1, 1	3235·3	6	4, 1	2969·1	6	6, 0

System B, Blue

Appearance. Degraded to the red. Double double-headed bands.

Transition. $B\,^2\Sigma \rightarrow A\,^2\Pi$.

The following are the strong heads. Intensities have been raised to a scale of 10 for the strongest band of System A.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4653·0	4	2, 2 Q_2	4551·3	4	0, 0 R_2	4454·7	6	3, 2 Q_1
4619·1	4	2, 2 Q_1	4524·6	8	0, 0 Q_1	4438·7	4	2, 1 R_2
4605·3	4	1, 1 Q_2	4517·5	3	0, 0 R_1	4434·2	4	2, 1 Q_2
4572·0	4	1, 1 Q_1	4502·2	4	4, 3 Q_1	4407·7	4	2, 1 Q_1
4557·3	8	0, 0 Q_2	4486·3	5	3, 2 Q_2	4392·8	3	1, 0 Q_2

CS

Occurrence. In vacuum tube discharge through carbon disulphide and in carbon arc fed with sulphur ; also in low temperature phosphorescent flame of CS_2. The bands are frequently encountered as an impurity in discharge tube spectra.
Appearance. Degraded to the red. Close double-headed bands. The sequences are fairly obvious ; the head of the (0, 0) band at 2576 A. is often very outstanding. See Plate 5.
Transition. Probably $^1\Pi \rightarrow {}^1\Sigma$, ground state.
References. L. C. Martin, *P.R.S.*, **89**, 127. (1913)†.
W. Jevons, *P.R.S.*, **117**, 351. (1928).
F. H. Crawford and W. A. Shurcliff, *P.R.*, **45**, 860. (1934).

The following are the R heads of all the prominent bands as measured by Jevons. The Q heads lie from 0·5 to 2 A. to the red of the R heads. Intensities given below are for a discharge through CS_2.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2852·3	2	0, 3	2677·0	6	1, 2	2523·2	7	2, 1
2836·8	2	5, 7	2662·6	10	0, 1	2511·2	3	6, 4
2819·5	3	4, 6	2638·9	2	4, 4	2507·3	4	1, 0
2801·5	5	3, 5	2621·6	7	3, 3	2493·7	6	5, 3
2785·7	5	2, 4	2605·9	10	2, 2	2477·0	4	4, 2
2769·2	3	1, 3	2589·6	6	1, 1	2473·4	3	8, 5
2754·7	7	0, 2	2575·6	10	0, 0	2460·2	5	3, 1
2743·9	3	5, 6	2572·7	5	5, 4	2454·3	1	7, 4
2726·7	4	4, 5	2555·8	5	4, 3	2444·8	3	2, 0
2708·9	7	3, 4	2538·7	8	3, 2	2436·0	1	6, 3
2693·2	8	2, 3	2530·0	3	7, 5	2418·4	0	5, 2

CS_2

Occurrence. Absorption by carbon disulphide vapour.
Appearance. A very complex system of headless bands.
Reference. E. D. Wilson, *Astrophys. J.*, **69**, 34. (1929).

The following are the strongest maxima, with intensities reduced to a scale of 10 from Wilson's measurements.

λ	I	λ	I	λ	I	λ	I
3346·0	1	3227·4	3	3154·0	5	3080·7	4
3321·6	2	3214·3	7	3150·9	6	3056·8	2
3301·3	2	3204·4	9	3144·0	8	3036	2
3274·8	8	3189·5	10	3126·6	6	3023	2
3260·4	2	3181·5	6	3119·3	6	3009·4	1
3250·6	5	3170·2	6	3100·4	4	2993·4	1
3235	8	3161·9	5	3092·5	5		

CSe

Occurrence. High-frequency discharge through selenium vapour in a quartz tube on which carbon has been deposited.
Appearance. Degraded to the red. Some of the bands show double heads (separation about 5 A.).

CSe (*contd.*)

Transition. Probably $^1\Pi \rightarrow {}^1\Sigma$.

Reference. B. Rosen and M. Désirant, *C.R. Acad. Sci. Paris*, **200**, **1659**. (1935).

The following are the stronger (presumably the R) heads of the bands observed :—

λ	v′, v″	λ	v′, v″	λ	v′, v″
3053·3	2, 4	2963·9	2, 3	2861·6	1, 1
3038·3	1, 3	2948·0	1, 2	*2844·5	0, 0
3021·1	0, 2	2931·0	0, 1	2779·1	1, 0

* The (0,0) band is stated to be the strongest ; the weaker Q head is at 2848·9 A.

CaBr

There are two systems, one in the red and the other in the violet, attributed to CaBr. In addition, a few weak bands have been observed in the ultra-violet.

Red System

Occurrence. In absorption and when calcium bromide is introduced into a flame ; the bands do not appear readily in an arc.

Appearance. Marked close sequences degraded to shorter wave-lengths.

Transition. Perhaps $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. K. Hedfeld, *Z.P.*, **68**, 610. (1931).

O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).

The following measurements and analysis are by Hedfeld. The intensities I_a and I_f are for absorption and for emission in a flame respectively, the former being by Walters and Barratt, who also report a band (intensity 5) at 6106·6.

λ	I_a	I_f	Sequence	λ	I_a	I_f	Sequence
6399·0		0	0, 1 P_1	6258·8	0	5	0, 0 P_2
6390·5	0	0	0, 1 Q_1	6252·9	10	10	0, 0 Q_2
6370·9		0	0, 1 P_2	6176·8		0	1, 0 P_1
6364·8	0	0	0, 1 Q_2	6168·8	0	0	1, 0 Q_1
6286·0	0	4	0, 0 P_1	6150·6		0	1, 0 P_2
6277·7	10	10	0, 0 Q_1	6145·0	0	0	1, 0 Q_2

Violet System

Occurrence. In absorption and in flame.

Appearance. Degraded to longer wave-lengths. Close sequences.

References. C. M. Olmsted, *Zeit. f. wissen. Photographie*, **4**, 255. (1906).

O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).

The following measurements of the strong bands are compiled from the above. Intensities I_a and I_f for absorption and flame.

λ	I_a	I_f	λ	I_a	I_f
3996	0	5	3917	4	6
3960	0	4	3910	0	3
3951	4	6	3878		4

Ultra-violet Bands

Weak bands (intensity 0), degraded to shorter wave-lengths, reported by Walters and Barratt at λλ2967, 2952, 2945, 2910 and 2890, in absorption.

CaCl

Occurrence. When $CaCl_2$ is introduced into an arc or flame.
Also in absorption, frequently as an impurity.

References. K. Hedfeld, *Z.P.*, **68**, 610. (1931).
A. E. Parker, *P.R.*, **47**, 349. (1935).

There are three strong systems, in the red, orange, and ultra-violet respectively. A few weak fragmentary systems are also reported by Parker.

RED SYSTEM, λλ6361–6047

Appearance. Degraded to violet. Marked close sequences.
Transition. Perhaps A $^2\Pi \rightarrow {}^2\Sigma$, ground state. Strongest heads :—

λ	I	v′, v″	
6353·5	2	0, 1	Q_1
6325·8	2		Q_2
6224·9	5	0, 0	P_1
6211·6	10		Q_1
6193·4	5		P_2
6184·9	10		Q_2
6076·6	2	1, 0	Q_1
6051·6	2		Q_2

ORANGE SYSTEM, λλ6067–5810

Appearance. Degraded to red. Close sequences.
Transition. Perhaps B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.
λ5934·0 head of (0, 0) sequence, intensity 10.
λ5809·9 ,, ,, (1, 0) ,, ,, 4.

ULTRA-VIOLET SYSTEM, λλ4023–3644

Appearance. Degraded to red. Close sequences.
Transition. Perhaps C $^2\Pi \rightarrow {}^2\Sigma$, ground state.
No intensities given. Heads of sequences :—

λ	Sequence	
3828·1	0, 1	Q_1
3816·9		Q_2
3775·0	0, 0	Q_1
3774·4		R_1
3764·2		Q_2
3763·5		R_2
3728·0	1, 0	Q_1
3727·4		R_1
3717·3		Q_2

CaF

Occurrence. When calcium fluoride is put in carbon arc or a flame. These bands often occur as impurities in arc spectra and have been recommended for use in analytical work as a test for the presence of fluorine. Also in absorption.

References. S. Datta, *P.R.S.*, **99**, 436. (1921)†.
R. C. Johnson, *P.R.S.*, **122**, 161. (1929).
A. Harvey, *P.R.S.*, **133**, 336. (1931)†.

CaF (*contd.*)

There are three systems usually known as the orange, green and ultra-violet systems. The two former appear strongly, but the ultra-violet bands are weak and usually masked by CaO bands.

ORANGE SYSTEM

Transition. A $^2\Pi \rightarrow {}^2\Sigma$, ground state.

There are long sequences of heads of about equal intensity. The (0, 1) and (0, 0) sequences are degraded to the violet, the separation between successive heads being about 4·5 A. for the (0, 1) sequence and 2 A. for the (0, 0). The (1, 0) sequence is piled up on itself and shows a head at 5830 A., degraded to the red. See Plate 1.

The heads of the sequences only are listed :—

λ	I	Sequence	
6285·3	4	(0, 1)	Q_{12}
6256·6	4	(0, 1)	Q_2
6086·9	5	(0, 0)	P_{12}
6064·4	10	(0, 0)	Q_{12}
6050·8	6	(0, 0)	P_2
6036·9	6	(0, 0)	Q_2
5830	5	(1, 0)	Degraded to red

GREEN SYSTEM

Transition. B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

Strong (0, 0) sequence of double-headed bands degraded to the red. The heads are separated by about 1·8 A., and successive bands of the sequence by about 6 A. There is a weaker (1, 0) sequence of similar appearance. See Plate 1.

λ	v′, v″	
5291·0	(0, 0)	R_2
5292·9	(0, 0)	R_1
5296·8	(1, 1)	R_2
5298·6	(1, 1)	R_1
etc.		
5145·4	(1, 0)	R_2
5146·4	(1, 0)	R_1
5151·9	(2, 1)	R_2
5152·8	(2, 1)	R_1
etc.		

ULTRA-VIOLET SYSTEM

Transition. C $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Two sequences degraded to the red ; no intensities given. The first few heads of each sequence as measured by Datta are given :—

λ	λ
3371·1	3449·2
3373·2	3459·9
3382·6	3462·0
3384·6	3470·6
3393·7	3472·8
3395·9	3481·2
etc.	etc.

CaH

Five systems have been observed and analysed, of which the strongest are systems A and B.

References. E. Hulthén, *P.R.*, **29**, 97. (1927).
B. Grundström, *Z.P.*, **69**, 235 (1931)†.
Z.P., **75**, 302 (1932).
Z.P., **95**, 574 (1935).
W. W. Watson and R. L. Weber, *P.R.*, **48**, 732. (1935).

6946 A. A-System, A $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Bands degraded to the violet. Obtained in calcium arcs in hydrogen at various pressures. Observed in absorption by mixture of hydrogen and calcium vapour. Identified in the sun-spot spectrum.

v,′ v″	Origins	Heads			
0, 1	7613				
1, 2	7571				
0, 1	7567				
2, 3	7531				
1, 2	7525				
2, 3	7484				
0, 0	6946	6942·6	Q_1	7028	P_1
1, 1	6930	6928·6	Q_1	7006	P_1
0, 0	6908	6919·8	Q_2	7035	P_2
1, 1	6891	6902·6	Q_2	7005	P_2

6346 A. B-System, B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

Bands degraded to the violet. Occurrence similar to A-System.

v′, v″	Origins	Heads			
2, 2	6358				
1, 1	6352				
0, 0	6346	6389·3	P_1	6382·1	P_2

3534 A. C-System, C $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

Bands degraded to the violet forming fairly sharp P heads. Complete system observed at high pressures of hydrogen (3–4 atms.).

v′, v″	P. Heads
0, 1	3697
0, 0	3534
1, 1	3515
2, 2	3498
3, 3	3482
1, 0	3368
2, 1	3356
3, 2	3347
4, 3	3338
5, 4	3331

CaH (*contd.*)

4500 A. D-System, D $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

Bands degraded to the red. System less intense than A and B. The R heads very weak.

v′, v″	Origins
0, 3	5301
0, 2	4988
1, 2	4732
0, 1	4702
1, 1	4473
1, 0	4235
2, 0	4059

4900 A. E-System, $^2\Pi \rightarrow {}^2\Sigma$

Weak system slightly degraded to the violet. Observed in arc in hydrogen at low pressure with water-cooled copper cathode and anode of metallic calcium.

v′, v″	Origin	Heads	
0, 0	4900	4898·1 Q_1	4899·1 Q_2
1, 1		4915·7 Q_1	4916·6 Q_2
2, 2		4934·8 Q_1	4935·8 Q_2

CaI

There are bands in the red and violet attributed to CaI, and a few weak bands in the ultra-violet.

Red Bands.

Occurrence. In absorption and in a flame.
Appearance. Marked close sequences, degraded to the violet.
References. K. Hedfeld, *Z.P.*, **68**, 610. (1931).
O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928)†.

The bands have been analysed by Hedfeld into three overlapping systems with the same final levels. These systems are denoted by I, II and III, and the intensities I_a and I_f are given for absorption (Walters and Barratt) and emission in a flame.

λ	I_a	I_f	Sequence	λ	I_a	I_f	Sequence
6513·7	1	0	0, 1 Q I	6388·8	10	9	0, 0 Q II
6488·7	1	0	0, 1 Q II	6363·2		0	0, 0 P III
6460·2	1	0	0, 1 Q III	6361·3	6	3	0, 0 Q III
6419·3		1	0, 0 P I	6315·4	8	0	1, 0 Q I
6412·9	10	6	0, 0 Q I	6291·9	6	0	1, 0 Q II
6392·7		0	0, 0 P II	6265·1	8	0	1, 0 Q III

Violet Bands

Occurrence. In absorption and in a flame.
Appearance. Close sequences degraded to the red.
References. C. M. Olmsted, *Zeit. f. wissen. Photographie*, **4**, 255. (1906).
O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).

CaI (*contd.*)

Strong bands compiled from the above references. Intensities I_a and I_f for absorption and flame.

λ	I_a	I_f
4334	1	3
4308		2
4289	5	4
4255	1	3
4250	0	2
4211	2	4
4176		2

Ultra-violet Bands

Observed in absorption by Walters and Barratt. Degraded to shorter wavelengths.

λ	I
3266	0
3215	3
3186	3
3158	1
3127	1

CaO

When calcium salts are introduced into a flame or arc strong band systems are observed in the infra-red, extreme red, orange and green, and in an arc or hollow cathode discharge there are several weaker systems in the blue, violet and near ultra-violet. The bands in the green and orange are attributed by Mahanti and by King to Ca_2, but this assignment is contrary to our experience, which indicates CaO as the emitter. Brodersen apparently includes the green system in his term scheme for CaO, but omits the orange bands. Further work on these orange and green systems, which appear very readily and are a frequent impurity in arc spectra, seems desirable; a rotational analysis made from large dispersion spectrograms might give conclusive results.

Infra-red System

Appearance. Degraded to the violet. Three close sequences have been observed.
Reference. W. F. Meggers, *Bur. Stand. Jour. Res.*, **10**, 669. (1933).

λ	I	v′, v″	λ	I	v′, v″
10533	3	0, 0	9807·3	20	2, 1
10492	4	1, 1	9775·0	15	3, 2
10444·7	5	2, 2	9741·0	5	4, 3
10396·7	6	3, 3	9700·0	10	5, 4
10339·8	5	4, 4	9229	20	2, 0
10289·5	5	5, 5	9215·1	5	3, 1
9834·7	30	1, 0	9193·4	2	4, 2

Extreme Red System

References. W. F. Meggers, see above.
P. H. Brodersen, *Z.P.*, **79**, 613. (1932) †; and *Z.P.*, **104**, 135. (1936).

CaO (*contd.*)

The analyses proposed by Meggers and by Brodersen differ in detail. The near equality between ω' and ω'' results in some uncertainty in the assignment of vibrational quantum numbers. The following measurements are compiled from the above references, intensities where given being by Meggers.

λ	I	λ	I	λ	I	λ	I
8651·9	20	8153·0	40	7327·7	2	6968·6	2
8643·0	2	7721·1	4	7318·5	3	6956·0	2
8629·2	1	7715·7	5	7308·4	2	6639·2	
8167·0	5	7339·0		6983·2	3	6625·0	

Orange System

Occurrence. These bands occur very strongly and with great persistence when calcium salts are introduced into an arc in air. A. S. King (*Astrophys. Jour.*, **27**, 353 (1908)) reports that bands occur in a furnace spectrum of calcium in hydrogen and therefore concludes that they are due to Ca_2 or CaC. This is contrary to our experience ; the bands do not occur with calcium chloride in an arc in hydrogen, and in view of the affinity of metallic calcium for water it is difficult to be sure that a little CaO was not present in King's experiments.

Appearance. A complex system of bands with heads degraded in each direction. See Plate 1.

The following are the most prominent features, being rough measures from our plates taken in the second order of a 20-ft. concave grating. The letters R, V or M indicate direction of degradation of the head.

λ		I	λ		I	λ		I
6362	M	4	6183	V	6	6065	R ?	5
6344	M	4	6097	V	10	6056	R	5
6318	M	2	6092	V	6	6041	R	3
6281	M	3	6088	R ?	5	6006	V	8
6278	V	4	6075·5	V	5	6003	R	8
6262	M	8	6069	V	7	5983	R	8
6258·5	V	9						

Green System

Occurrence. As for orange system.

Appearance. A diffuse banded structure, apparently without rotational fine structure, extending from 5473 A. to about 5560 A. Under small dispersion the appearance is of a diffuse band with head at 5473 A. degraded to the red. Under large dispersion the head is less obvious, but there are maxima of intensity at about λλ5506, 5498, 5496, 5492, 5488, 5484, 5476 and 5473 ; the head at λ5498 is relatively strong and appears to be shaded to the red. See Plate 1.

Blue System

Occurrence. Weak bands in the blue and violet are observed in flames and arcs into which calcium salts are introduced ; the bands have also been observed in a hollow cathode discharge.

Appearance. Degraded to the red.

References. P. C. Mahanti, *P.R.*, **42**, 609. (1932)†.
P. H. Brodersen, *Z.P.*, **104**, 135. (1936–37).

CaO (*contd.*)

Mahanti has analysed the bands into a single system ; the observed and calculated band heads agree to about one wave-number and the listed intensities are quite smooth, but the published spectrograms do not inspire confidence. Brodersen has analysed the bands into several systems and his wave-lengths differ considerably from Mahanti's, but in the absence of published photographs or even estimated intensities it is difficult to compare the merits of the two papers. Further work on these bands is desirable.

The following are the strongest bands as observed by Mahanti ; intensities on a scale of 6. Asterisks indicate that these bands have also been observed by Brodersen.

λ	I	λ	I	λ	I
4519·1	3	4366·7	5	4126·0	3
4505·0	4	*4351·2	5	*4104·1	4
4425·8	3	*4240·8	3	*4084·3	5
*4403·9	6	4221·9	5	*3973·9	3
*4384·8	6	*4205·1	6	*3872·9	2

Ultra-violet System

Occurrence. As for blue system. These bands are stronger and more definite than those in the blue.
Appearance. Degraded to the red.
References. See blue system.

The following measurements are by Mahanti. Strongest bands :—

λ	I	v′, v″	λ	I	v′, v″
3753·2	3	0, 3	3494·7	3	1, 1
3676·5	3	1, 3	3475·0	6	0, 0
3656·6	4	0, 2	3409·1	4	1, 0
3583·7	3	1, 2	3346·7	3	2, 0
3564·0	5	0, 1	3287·4	3	3, 0

Cd_2

Several papers have appeared on the emission, absorption and fluorescence spectra of cadmium and there has been some controversy on the origin of the various bands which have been observed. The bands and continua produced by the Cd_2 molecule have been listed by Cram.
Reference. S. W. Cram, *P.R.*, **46**, 205. (1934).

λ2124

A narrow band between 2140 and 2110 A. has been observed in emission (in discharge tubes, especially ring discharges), absorption and fluorescence.

λ2212

A narrow band has been observed at 2212 A. in absorption ; it is probably due to an impurity.

Cd_2 (*contd.*)

λ2288

A broad band with maximum at 2288 A. has been observed in emission, absorption and fluorescence; flutings are superposed on the red side of this. The limits and regions of the flutings are roughly :—

Source	Limits	Region of Fluting
Emission . . .	2191–3050	—
Absorption . .	2212–3050	2590–2825
Fluorescence . .	2260–3050	2700–3050

λ3178

Narrow band at 3178 in emission, absorption and fluorescence.

λ3261

Band overlapping Cd line at 3261, in emission, absorption, and fluorescence.

Blue Region

Broad band observed in emission and fluorescence.

Emission . . .	4058–5400 A.
Fluorescence . .	3800–5000 A., maximum at 4000 A.

CdBr

Bands $\lambda\lambda$3247–3122 have been observed in discharge tubes containing $CdBr_2$. They are degraded to shorter wave-lengths.

Reference. K. Wieland, *Helv. Phys. Acta.*, **2**, 42. (1929).

Heads of strongest sequences :—

λ	I	Sequence
3223·4	4	0, 2
3199·9	8	0, 1
3176·6	9	0, 0
3151·3	7	1, 0
3126·5	2	2, 0

Bands $\lambda\lambda$3551–3407 observed by Walter and Barratt (*P.R.S.*, **122**, 201 (1929)) in absorption are apparently the same as the thallium bromide bands, TlBr.

$CdBr_2$

Diffuse bands in the region 6400 A. to 3300 A. have been observed in emission by K. Wieland (see CdBr above) ; the bands may be degraded to the red.

CdCl

Bands $\lambda\lambda$3400–3300 are reported in emission in a discharge tube containing $CdCl_2$ by Wieland ; the bands are degraded to shorter wave-lengths, but no wave-lengths are given. Walter and Barratt have observed bands $\lambda\lambda$3181–3018 in absorption.

References. K. Wieland, *Helv. Phys. Acta.*, **2**, 46. (1929).
J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).

CdCl (*contd.*)

Strongest absorption bands recorded by Walter and Barratt :—

λ	I	λ	I
3181	5	3074	2
3174	2	3072	5
3172	5	3066	4
3163	3	3060	3
		3054	2

$CdCl_2$

Diffuse bands, degraded to the red, from 6400 to 3300 A. are reported by Wieland (see above under CdCl) in discharge tubes containing $CdCl_2$.

CdF

Bands in the orange and yellow-green observed by Asundi, Samuel and Zaki-uddin (*Proc. Phys. Soc.*, **47**, 235 (1935)) have been identified with calcium fluoride.

We have observed the following bands in an arc between cadmium electrodes fed with cadmium fluoride ; their assignment to CdF is uncertain. The letters R and V indicate that the band is degraded to longer or shorter wave-lengths.

λ	I	λ	I
3005 R	5	2904 R	1
2961·5 V	5	2862 V	5
2908 R	2	2819 V	3

CdH

Reference. E. Svensson, *Z.P.*, **59**, 333. (1930).

4500 A. System, A $^2\Pi \rightarrow {}^2\Sigma$ ground state.

Bands degraded to the violet, each with P, Q and R branches. The system is easily obtained in discharges where cadmium vapour is mixed with hydrogen. See Plate 4.

$^2\Pi_{1/2} \rightarrow {}^2\Sigma$				$^2\Pi_{3/2} \rightarrow {}^2\Sigma$			
v′, v″	Origins	P Heads	Q Heads	v′, v″	Origins	P Heads	Q Heads
0, 4	5624			0, 2	4835		
0, 3	5368	5368·7	5359·3	1, 3	4693		
1, 4	5146	5146·1	5141·2	0, 1	4571		
0, 2	5080	5081·7	5071·1	1, 2	4470		
1, 3	4926			0, 0	4300	4313·3	4297·6
0, 1	4791	4791·1*	4777·4	1, 1	4247		
1, 2	4683			1, 0	4026	4026·7	4008·5
0, 0	4500	4509·0	4491·3	2, 1	3980	3980·4	3965·6
1, 1	4437			2, 0	3789		
1, 0	4198	4198·6	4177·3				

* Line-like head.

Note. The values of λ given to 0·1 A. were taken from the rotational analysis ; other values from the energy-level diagram.

CdH (*contd.*)

3520 A. SYSTEM, B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

Bands showing double P and double R branches degraded to the red.

v′, v″		R Heads
0, 0	3520	3524·3
1, 0	3420	3422·4
2, 0	3332	3332·2
3, 0	3249	3249·8
4, 0	3174	3174·3
5, 0	3105	
6, 0	3042	3042·9
7, 0	2980	2985·6

4930 A. SYSTEM, C $^2\Sigma \rightarrow$ A $^2\Pi$

Obtained under the same conditions as above. Band degraded to the red.

Q Head
4933·6

CdH+

References. E. Svensson and F. Tyrén, *Z.P.*, **85**, 257. (1933).
E. Bengtsson and R. Rydberg, *Z.P.*, **57**, 648. (1929).

2341 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$

Extensive system of singlet bands degraded to the red. System occurs with cadmium arc in hydrogen at low pressure; and in discharges through a mixture of hydrogen and cadmium vapour where ionisation is favoured, such as hollow cathode or high-frequency discharge.

v′, v″	R Heads	I
3, 1	2239·8	4
1, 0	2275·2	5
0, 0	2340·9	8
0, 1	2437·9	10
1, 2	2461·3	8
2, 3	2481·4	6
0, 2	2538·2	8
1, 3	2558·5	8
2, 4	2574·8	7
3, 5	2587·3	4

CdI

Bands λλ3517–3288 have been observed in discharge tubes containing CdI_2; they are degraded to shorter wave-lengths.

Reference. K. Wieland, *Helv. Phys. Acta.*, **2**, 46. (1929).

Heads of strongest sequences :—

λ	I	Sequence
3404·8	5	0, 1
3384·4	7	0, 0
3362·2	5	1, 0
3340·8	3	2, 0

Bands λλ4301–3806 reported in absorption by Walter and Barratt (*P.R.S.*, **122**, 201 (1929)) appear to be due to thallium and bismuth iodides, TlI and BiI.

CdI_2

A continuum 6600–3600 A. and a system of bands λλ2550–2350 are reported by Wieland (see above under CdI) in discharge tubes containing CdI_2. The bands are degraded to the red, strongest heads λλ2441·9, 2425·8, 2425·4, 2415·6, 2399·6 and 2389·6.

CdIn

Bands observed in absorption and attributed to the mixed metal molecule InCd by Waring (*P.R.*, **32**, 435 (1928)) have been identified with bismuth Bi_2 by Barratt and Bonar (*Phil. Mag.*, **9**, 519 (1930)).

CdO

Bands observed in absorption by cadmium in the presence of oxygen by Walter and Barratt (*P.R.S.*, **122**, 201 (1929)) have since been identified with bismuth Bi_2 by Barratt and Bonar (*Phil. Mag.*, **9**, 519 (1930)).

CdS

Continuous absorption.

Reference. P. K. Sen Gupta, *P.R.S.*, **143**, 438. (1933–4).

CeO

Occurrence. Cerium oxide or chloride in arc.
Appearance. All bands are degraded to longer wave-lengths.
Reference. W. W. Watson, *P.R.*, **53**, 639. (1938).

System A.

Single-headed bands :—

λ8396 head of (0, 1) sequence.
λ7879·3 (1, 1) band.
λ7831·8 head of strong (0, 0) sequence.
λ7380 head of (1, 0) sequence.

Systems B and C

These overlap and appear as a double-headed system.
λ7716 head of (0, 1) sequence of System B.
λ7347 (1, 1) band of System C.
λ7297·2 (0, 0) sequence of System C.
λ7275·5 (1, 1) band of System B.
λ7235·8 (0, 0) sequence of System B.
λ6847 (1, 0) sequence of System B.

Systems D and E

λ4863·2 (0, 0) sequence of System D.
λ4791·7 (0, 0) sequence of System E.
λ4683 (1, 0) sequence of System D.
λ4614 (1, 0) sequence of System E.

Cl_2

Absorption Spectrum

Chlorine gas shows a strong continuous absorption extending from the blue to around 2500 A. and having a maximum around 3300 A.

In greater thicknesses (1 metre at atmospheric pressure) there is also a banded absorption spectrum extending from 4800 A. to the red. Full measurements of the individual lines of this system have been published by Laird and a vibrational and rotational analysis is given by Elliott. The bands are strongly degraded to the red and the bands do not show well-developed heads.

References. E. R. Laird, *Astrophys J.*, **14**, 85. (1901).
A. Elliott, *P.R.S.*, **123**, 629. (1929)†.
P.R.S., **127**, 638. (1930).

Emission Spectrum

The various emission spectra of chlorine as obtained in various sources have been summarised by Elliott and Cameron.

References. A. Elliott and W. H. B. Cameron, *P.R.S.*, **158**, 681. (1937).
W. H. B. Cameron and A. Elliott, *P.R.S.*, **169**, 463. (1939).

Source	Spectrum	Observer
Discharge tube.	Bands 4871–3923 A.	Ota and Uchida.
Tesla discharge.	Continua ; maxima 3070 A. and 2600 A.	Ludlam and West.
Positive point discharge.	Bands 4000–3100 A. Continua 2960 A., 2485 A.	Campetti.
Cl_2 in active nitrogen.	Continuum 2600–2540 A.	Strutt and Fowler.
Cl_2 burning in H_2.	Bands 6500–5590 identical with absorption bands.	Kitagawa.
Cl_2 at high temperature.	Continuum in blue-green.	Kondratjew and Leipunski.
Discharge tube at high pressure.	Continua, max. 3070 and 2570 A.	v. Angerer.
High-frequency discharge.	Bands as for discharge tube; continua, max. 3063, 2957, 2881, 2819, 2758, 2714, 2564, 2432.	Elliott and Cameron.

The blue-violet emission bands obtained in ordinary discharge tubes, and high-frequency discharges have recently been attributed by Elliott and Cameron to the ionised molecule Cl_2^+.

Cl_2^+

Occurrence. Discharge tubes containing chlorine, including high-frequency discharge.

Appearance. Degraded to the red. Most of the bands are double-headed, probably due to isotope effect.

Transition. Probably $^2\Pi \rightarrow {}^2\Pi$.

References. Y. Ota and Y. Uchida, *Jap. J. Phys.*, **5**, 53. (1928)†.
A. Elliott and W. H. B. Cameron, *P.R.S.*, **158**, 681. (1937)†.
P.R.S., **164**, 531. (1938).

The following are the strong bands as shown in the published photographs, with our estimates of intensity from these photographs. Measurements are from both

Cl_2^+ (*contd.*)

Ota and Uchida and from Elliott and Cameron's first paper. For double bands, only the first head is given. Elliott and Cameron do not agree with Ota and Uchida's vibrational analysis. The analysis given here, for those bands which have been identified, is Elliott and Cameron's. This is presumably checked by the rotational analysis, but the intensity distribution of the vibrational scheme is not very satisfactory. The letters i and ii denote the sub-system of the $^2\Pi \rightarrow {}^2\Pi$ transition to which the band belongs.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4870·9	7		4442·3	6		4194·7	7	
4853·9	7	8, 7 i	4421·5	6	5, 1 ii	4140·1	8	9, 2 i
4794·7	9	?	4407·5	6	6, 2 i	4112·8	6	8, 1 i
4751·0	9	4, 3 i	4381·0	5	5, 1 i	4041·7	7	
4682·6	10	5, 3 ii	4348·5	5	7, 2 ii	4033·0	7	
4613·6	9	4, 2 i	4316·0	7		3979·4	6	
4549·1	10	5, 2 ii	4285·6	6	6, 1 i	3961·4	5	9, 0 ii
4506·2	8		4252·4	5		3941·3	5	
4487·5	8	4, 1 i ?	4231·5	7	7, 1 ii			

ClO_2

Occurrence. Absorption by chlorine dioxide.

Appearance. Degraded to the red. This is, for a triatomic molecule, a remarkably regular system of well-defined single-headed bands. The bands are strongest in the region 3700 A. to 3200 A., but extend as far as the blue when sufficient thickness of gas is used. The bands occur in regularly spaced groups, each group consisting of one strong band and two or three weaker bands to the shorter wave-length side.

References. C. F. Goodeve and C. P. Stein, *Trans. Faraday Soc.*, **25**, 738. (1929)†.
H. C. Urey and H. Johnston, *P.R.*, 38, 2131. (1931).
Z. W. Ku, *P.R.*, 44, 376. (1933)†.

The following are the strong heads of the regularly spaced groups ; these bands are accompanied by weaker bands to shorter wave-lengths, this being especially true of the bands at the visible end of the system. No intensities are available, but from Goodeve and Stein's published photograph it is seen that the band groups are very smooth in intensity distribution, the bands in the central region being the strongest.

λλ4199·4, 4082·5, 3972·8, 3869·7, 3772·5, 3680·5, 3594·1, 3511·4, 3434·0, 3360·5, 3291·2, 3226·0, 3163·5, 3105·7, 3050·9, 2999·4, 2953·5.

CoBr or $CoBr_2$

Occurrence. Cobalt bromide in high-frequency discharge.

Reference. P. Mesnage, *Thesis for doctorate, Paris.* (1938).

The following are the strongest bands ; bands degraded to the red, to shorter wave-lengths or headless bands showing only a maximum of intensity are denoted by the letters R, V or M :—

λ	I	λ	I	λ	I
5637·4 R	8	5528·3 R	7	4493·7 R	4
5558·2 R	5	5455 M	5	4462·3 R	4
5553·5 R	5	4749·2 R	6	4366·5 V	3
5547·0 R	6	4559·8 R	5	4337·9 R	6
5542·2 R	6	4540·9 R	4		

CoCl or $CoCl_2$

Occurrence. Cobalt chloride in high-frequency discharge.
Reference. P. Mesnage, *C.R. Acad. Sci., Paris,* **201,** 389 (1935); and *Thesis for doctorate, Paris.* (1938).

The following are the strongest bands; bands degraded to the red, to shorter wave-lengths or headless bands showing only a maximum of intensity are denoted by the letters R, V or M:—

λ	I	λ	I	λ	I
6216·6 V	4	5737·9 M	10	4833·4 R	6
6033·4 V	4	5669·8 V	8	4702·3 R	5
5843·1 V	4	5668·2 M	10	4541·2 R	5
5837·5 V	8	5667·0 M	5	4506·8 R	7
5832·2 V	5	5565·2 R	5	4352·7 R	5
5742·0 M	5				

CoH

Reference. A. Heimer, *Z.P.*, **104,** 448. (1937).

4494 A. SYSTEM, $^3\Phi_4 \rightarrow {}^3\Phi_4$

Bands degraded to the red. P and R branches widely spaced and Q branch strong near the origin but quickly dying out with increasing rotation. Bands obtained with electric furnace (King's type).

	Heads	
v′, v″	R	Q
0, 0	4477·9	4495·0
1, 0	4194·5	4206·3

CrCl

Bands in the region 2600 A. observed by Mesnage in a high-frequency discharge through a heated quartz tube containing chromium chloride appear to be due to aluminium chloride. Mesnage also reported diffuse bands, perhaps due to $CrCl_2$, in the red with maxima at λλ6268–59, 6005, and 5862–44.

References. P. Mesnage, *C.R. Acad. Sci. Paris,* **201,** 389. (1935).
A. G. Gaydon and R. W. B. Pearse, *Nature,* **141,** 370. (1938).

CrH

Reference. A. G. Gaydon and R. W. B. Pearse, *Nature,* **140,** 110. (1937)†.

3675 A. SYSTEM

Band degraded to the violet obtained in the spectrum of a high-tension arc between chromium electrodes in a flame of hydrogen.

The band extends from a weak head at λ3700 to about λ3625 with a strong head at λ3675.

CrO

Occurrence. Chromium salts in carbon arc, and flame.
Appearance. Degraded to red.
Reference. C. Ghosh, *Z.P.*, **78,** 521. (1932)†.

CrO (*contd.*)

Strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
6891·5	5	2, 4	5794·4	8	1, 0
6829·7	6	1, 3	5623·3	5	3, 1
6771·8	6	0, 2	5564·1	5	2, 0
6451·5	7	1, 2	5416·5	4	4, 1
6394·3	9	0, 1	5356·4	3	3, 0
6051·6	10	0, 0	5168·2	3	4, 0

Cs_2

Several systems have been observed in absorption, and some of them in fluorescence. The character and relative strengths of the various systems are best seen from the photographs shown by Loomis and Kusch.

References. R. Rompe, *Z.P.*, **74,** 175. (1932).
F. W. Loomis and P. Kusch, *P.R.*, **46,** 292. (1934)†.

The following are the most important features in absorption :—

A strong system around 10, 500 A.

Diffuse bands, degraded to longer wave-lengths, in the near infra-red, heads λλ8733, 8346, 8262 and 8170.

Most intense system with origin at λ7667. The following heads are recorded by Rompe :—

λ	I
7680	0
7670	1
7640	2
7610	3
7540	5

A weak system of ten sharp heads, degraded to the red, 7400–7230.

A strong system with heads degraded to the violet at λλ7078, 7075, 7072 and diffuse bands 7185 and 7128.

A sharp head, degraded to the red, at λ6250 appears at rather high temperature. Also in fluorescence.

A system of moderate intensity around 4800 A.

Bands associated with 4555, 4593 Cs doublet.

A group of heads of moderate intensity at λλ3959, 3953, 3947, 3941, degraded to shorter wave-lengths.

λ3920, a weak head degraded to shorter wave-lengths.

Bands associated with 3889, 3877 Cs doublet.

CsCd

Barratt has studied the absorption spectra of mixed metallic vapours of the alkali-metals with zinc, cadmium and mercury. In most cases he observed diffuse bands, with a sharp head on the long wave-length side, extending to the violet as a weak continuum.

For CsCd he observed bands at λλ5316 and 5228.

Reference. S. Barratt, *Trans. Faraday Soc.*, **25,** 758. (1929).

CsH

Reference. G. M. Almy, and M. Rassweiler, *P.R.*, **53**, 890. (1938).

5500 A. System, $^1\Sigma \rightarrow {}^1\Sigma$, Ground State.

A many-lined system analogous to those of the other alkali hydrides obtained in absorption from a mixture of hydrogen and cæsium vapour at about 550° C.

Origins of the strongest bands :—

v′, v″	λ	v′, v″	λ
0, 2	6110·8	6, 0	5138·2
1, 2	6031·4	7, 0	5073·6
1, 1	5740·4	8, 0	5010·0
2, 1	5667·8	9, 0	4947·8
2, 0	5402·6	10, 0	4887·1
3, 0	5336·3	11, 0	4827·6
4, 0	5269·9	12, 0	4769·8
5, 0	5203·8	13, 0	4713·3

CsHg

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd). Heads λλ5343, 5222, 5112, 4932 and 4817. Mention is also made of sharp bands with heads at λλ4991, 4984 and 4975.

CsZn

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd). Heads λλ5163 and 5126.

CuBr

Occurrence. Three systems of bands have been observed in flames and in absorption.
Appearance. Degraded to red. Marked sequences.
Reference. R. Ritschl, *Z.P.*, **42**, 172. (1927).

The following measurements are by Ritschl; only the strong bands forming the heads of the sequences are given. Intensities, which have been increased to a scale of 10, are for absorption.

System A

λ	I	v′, v″
5032·2	3	0, 2
4954·7	4	0, 1
4883·4	4	1, 1
4879·3	8	0, 0
4810·4	2	1, 0

System B

λ	I	v′, v″
4461·9	4	0, 2
4400·9	4	0, 1
4341·1	10	0, 0
4288·6	7	1, 0
4237·8	4	2, 0

CuBr (*contd.*)

SYSTEM C

λ	I	v′, v″
4379·3	6	0, 2
4320·5	4	0, 1
4262·8	8	0, 0
4210·2	6	1, 0
4159·3	5	2, 0

CuCl

Occurrence. Five systems have been observed in flames, in fluorescence and in absorption. They also appear when CuCl is introduced into active nitrogen, and in an arc. The bands frequently occur as impurities in flame spectra. Systems D and E have been observed in discharge tubes containing CuCl.

Appearance. All five systems are degraded to the red, and form marked sequences. See Plate 6.

References. R. Ritschl, *Z.P.*, **42**, 172. (1927).
J. Terrien, *C.R. Acad. Sci. Paris*, **201**, 1029. (1935).

The following measurements are by Ritschl; only the strong bands forming the heads of the sequences are given. Intensities, which have been increased to a scale of 10, are for absorption.

SYSTEM A

λ	I	v′, v″
5380	2	0, 1
5262·3	4	0, 0
5152	2	1, 0

SYSTEM B

λ	I	v′, v″
4982·2	4	0, 1
4885·4	6	1, 1
4881·5	8	0, 0
4788·5	5	1, 0

SYSTEM C

λ	I	v′, v″
4949·8	5	1, 2
4946·1	4	0, 1
4851·2	6	1, 1
4846·9	8	0, 0
4755·7	5	1, 0

SYSTEM D, D $^1\Pi \rightarrow {}^1\Sigma$, GROUND STATE

λ	I	v′, v″
4515·9	1	0, 2
4433·8	6	0, 1
4358·1	5	1, 1
4353·9	9	0, 0
4280·9	7	1, 0
4211·0	4	2, 0

CuCl (*contd.*)

System E, E $^1\Sigma \rightarrow {}^1\Sigma$, Ground State

λ	I	v′, v″
4493·8	4	0, 2
4414·1	5	1, 2
4412·4	6	0, 1
4333·2	10	0, 0
4261·7	7	2, 1
4258·9	8	1, 0
4187·9	6	2, 0
4119·9	5	3, 0

CuF

Occurrence. Three systems have been observed in absorption, and system C has also been observed in an arc. The bands can probably be produced in flame sources as well.

Appearance. Degraded to violet. Marked sequences.

Reference. R. Ritschl, *Z.P.*, **42**, 172. (1927).

Strong bands as observed by Ritschl. Intensities, which are for absorption, have been increased to a scale of 8.

System A

λ	I	v′, v″
5694·3	6	0, 0
5685·7	6	1, 1
5677·2	5	2, 2

System B

λ	I	v′, v″
5061·1	7	0, 0
5052·3	6	1, 1
4901·3	5	1, 0

System C

λ	I	v′, v″
5086·4	2	0, 1
4932·0	8	0, 0
4926·8	6	1, 1
4781·9	4	1, 0

CuH

Six systems have been reported for CuH, of which the strongest is the 4280 A system.

References. A. Heimer and T. Heimer, *Z.P.*, **84**, 222. (1933).
T. Heimer, *Z.P.*, **95**, 321. (1935).

4280 A. System, $^1\Sigma \rightarrow {}^1\Sigma$, Ground State

Bands with single P and single R branches degraded to the red. R branches turn very near to the origin. Occurs in most sources where Cu vapour and hydrogen are present together. See Plate 4.

CuH (*contd.*)

v′, v″	Origins	R Heads
2, 3	4745·3	4734·1
1, 2	4701·5	4689·0
0, 1	4661·9	4648·4
2, 2	4387·4	4399·0
1, 1	4336·2	4327·7
0, 0	4288·6	4279·6
2, 1	4067·6	4061·9
1, 0	4011·5	4005·4
2, 0	3780·5	3776·3
3, 0	3586·2	3583·0

3804 A. SYSTEM, $^1\Sigma \rightarrow {^1\Sigma}$, GROUND STATE

P and R branches degraded to the red.

v′, v″	Origins	R Heads
1, 4	4800·9	
1, 2	4133·5	4127·4
0, 1	4094·6	4087·4
2, 2	3917·9	3914·3
1, 1	3848·4	3843·8
0, 0	3803·8	3798·6
2, 1	3660·8	
1, 0	3590·4	

3689 A. SYSTEM, $^1\Pi \rightarrow {^1\Sigma}$

P, Q and R branches degraded to the red.

v′, v″	Origins	R Head	Q Head
0, 0	3688·0	3684·0	3689·2
0, 1	3960·6		

3576 A. SYSTEM, $^1\Pi \rightarrow {^1\Sigma}$

P, Q and R branches degraded to the red.

v′, v″	Origins	R Head	Q Head
0, 1	3830·8		
0, 0	3575·1	3572·2	3576·3

3500 A. SYSTEM, $^1\Pi \rightarrow {^1\Sigma}$

P, Q and R branches degraded to the red.

v′, v″	Origin	R Head
0, 0	3500·9	3497

Reference. B. Grundström, *Z.P.*, **98**, 128. (1935)†.

2239 A. SYSTEM, $^1\Pi \rightarrow {^1\Sigma}$, GROUND STATE

Bands degraded to the red. Obtained in absorption.

v′, v″	Origins	R Heads	Q Heads
0, 0	2239	2228	2239·2
1, 1	2242	2234	2242

CuI

Occurrence. In flame spectra and on introduction of copper iodide vapour into active nitrogen. Also in absorption.

CuI (*contd.*)

Appearance. Degraded to red. Single-headed (apart from isotope shift). Close sequences.

Transition. There are five systems of bands A,B,C,D, and E all to the ground electronic state.

References. R. S. Mulliken, *P.R.*, **26, 1.** (1925).
R. Ritschl, *Z.P.*, **42,** 172. (1927).

The strongest bands listed by Mulliken (in active nitrogen) are given in the following tables. Intensities have been increased to a scale of 10.

SYSTEM A

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5494·1	3	4, 9	5312·4	5	2, 5	5117·3	3	3, 3
5477·1	4	3, 8	5297·5	6	1, 4	5101·9	3	2, 2
5461·3	3	2, 7	5283·8	4	0, 3	5072·8	10	0, 0
5402·2	5	3, 7	5241·0	3	2, 4	5034·6	3	2, 1
5386·5	6	2, 6	5226·1	5	1, 3	5019·7	7	1, 0
5371·5	5	1, 5	5212·2	7	0, 2	4983·9	4	3, 1
5357·4	3	0, 4	5155·8	3	1, 2	4968·3	5	2, 0
5328·5	3	3, 6	5141·1	7	0, 1	4919·1	3	1, 0

SYSTEM B

λ	I	v′, v″
4607·1	3	2, 2
4601·6	3	1, 1
4596·9	3	0, 0
4446·8	2	1, 0

SYSTEM C

λ	I	v′, v″
4694·0	2	1, 3
4687·8	3	0, 2
4630·6	5 ?	0, 1
4575·1	4	0, 0
4527·9	4	1, 0

SYSTEM D

λ	I	v′, v″	λ	I	v′, v″
4514·8	3	0, 3	4369·9	3	1, 1
4471·6	3	1, 3	4359·9	4	0, 0
4462·2	4	0, 2	4320·0	3	1, 0
4410·8	5	0, 1			

SYSTEM E

λ	I	v′, v″	λ	I	v′, v″
4425·1	2	3, 8	4280·1	2	3, 5
4419·1	3	2, 7	4261·7	5	0, 2
4413·7	2	1, 6	4227·0	4	2, 3
4369·9	3	2, 6	4214·6	4	0, 1
4364·0	4	1, 5	4180·8	2	2, 2
4358·3	3	0, 4	4174·6	4	1, 1
4315·4	3	1, 4	4168·5	1	0, 0
4309·6	4	0, 3	4129·4	2	1, 0
4286·5	2	4, 6	4091·3	3	2, 0

CuO

Occurrence. Copper arc in air or oxygen ; also copper salts in flame or in active nitrogen containing trace of oxygen.

Appearance. Degraded to longer wave-lengths. Widely spaced double-headed bands in orange.

References. R. S. Mulliken, *P.R.*, **26**, 1. (1925).
P. C. Mahanti, *Nature*, **125**, 819. (1930).
F. W. Loomis and T. F. Watson, *P.R.*, **48**, 280. (1935).

No accurate measurements of the heads have, to our knowledge, been recorded. The analysis proposed by Mahanti is doubted by Loomis and Watson. The following are our own measurements made from a spectrogram of the flame above a copper arc taken on the first order of a 20-ft. concave grating spectrograph. The heads in the orange region are complex, consisting of from four to six close heads of varying strengths ; only the outstanding heads are given. See Plate 6.

Orange Region

Intensities I_a are for our spectrogram of the arc ; intensities I_n are for active nitrogen, from Mulliken.

λ	I_a	I_n	λ	I_a	I_n	λ	I_a	I_n
6547	—	2	6376·9	2*	0	6059·3	10	7
6530	—	1	6294·0	5	2	6045·1	9	1
6493·4	1	1	6280·9	1	0	5847·6	3	—
6430·0	3	3	6161·5	9	8	5832·7	2	—
6400·4	5	1	6146·8	8	2	5827·7	1	—

* Recorded as intensity 8 by Hertenstein.

Green Region

There are a large number of weak bands in this region, including a little group of heads between 5237 and 5228 A and heads at 5344, 5313, 5308, 5279 and 5274 A.

F_2

Occurrence. Discharge through fluorine.

Appearance. Degraded to the red. Four strong bands roughly equally spaced, and a few weaker bands.

Transition. $^1\Pi \rightarrow {}^1\Sigma$.

References. H. G. Gale and G. S. Monk, *Astrophys. J.*, **59**, 125 (1924)† ; and **69**, 77. (1929)†.
J. Aars, *Z.P.*, **79**, 122. (1932)†.

The following wave-lengths are from Gale and Monk's first paper ; the intensities are our estimates from the published photograph. Owing to perturbations the vibrational analysis is difficult, and that proposed by Gale and Monk is unconvincing, although no alternative is obvious.

λ	I	λ	I
6977·0	0	5851·3	4
6927·2	0	5731·4	9
6518·6	10	5515·5	0
6488·7	5	5393·9	7
6102·6	10	5102·2	2

FeBr or $FeBr_2$

Occurrence. High-frequency discharge through iron bromide vapour.

Reference. P. Mesnage, *C.R. Acad. Sci. Paris,* **204,** 761 (1937); and *Thesis for doctorate, Paris.* (1938).

The following are the strongest bands: R, V or M indicate that the band is degraded to longer or shorter wave-lengths or that the measurement is of the maximum. No analysis is given.

λ	I	λ	I
6435 V	15	6187 M	10
6400 R	15	6146 M	4
6302 M	6	6081 M	4
6293 V	5	3694 V	4

FeCl or $FeCl_2$

Occurrence. High-frequency discharge through iron chloride vapour.

Reference. P. Mesnage, *C.R. Acad. Sci. Paris,* **201,** 389 (1935); and *Thesis for doctorate, Paris.* (1938).

The following are the strongest bands. The direction of degradation of each band is indicated as for FeBr. The bands have been analysed by Mesnage into several systems.

λ	I	λ	I	λ	I
6384·5 R	6	5989·4 V	6	3447·7 V	5
6378·0 R	5	5900·5 M	6	3432·0 V	4
6064·0 V	10	5801·4 M	8	3424·5 V	6
6060·2 V	7	4885·5 M	8	3416·1 V	7
6056·5 V	6	4877·5 M	6	3412·7 V	4
5989·8 V	7	4863·4 R	5	3366·8 V	4

FeH

Reference. A. Heimer, *Naturwiss.*, **24,** 491. (1936).

4288 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$ (?) *

Band degraded to the red.

v′, v″	Origin.
0, 0	4288

* Heimer reports the band as being of the type $^1\Sigma \rightarrow {}^1\Sigma$. If it is due to FeH the multiplicity should be even. FeH^+ would be expected to give odd multiplicity.

FeO

Bands in the orange and infra-red are observed in the flame surrounding an iron arc burning in air; the bands also appear very strongly and clearly when iron carbonyl vapour is introduced into a Bunsen flame. The bands are probably due to FeO. The following are our own measurements (A. G. Gaydon, *Ph. D. Thesis, London.* (1937)).

ORANGE SYSTEM

The following are the strong bands as observed in the iron carbonyl flame. Most of the bands are degraded to the red; headless bands are denoted by the letter M following the intensity. A few pairs of bands fall into a progression; vibrational quantum numbers are only tentative; the two sub-bands are denoted by i and ii. See Plate 5.

FeO (*contd.*)

λ	I	v′, v″	λ	I	v′, v″
6566·7	2	0, 3 i	5819·2	6	
6524·1	2	0, 3 ii	5807·4	2	
6218·9	10	0, 2 i	5789·8	9	
6180·5	9	0, 2 ii	5646·6	6	
6109·9	9 M		5624·1	4	
6097·3	9 M		5621·3	4	
5974·6	6		5614·0	6	0, 0 i
5919	4 M		5582·8	6	0, 0 ii
5911	4 M		5545	2	
5903·0	6	0, 1 i	5531·4	4	
5868·1	9	0, 1 ii	5430	2	

INFRA-RED SYSTEM

Degraded to longer wave-lengths. As observed in iron carbonyl flame.

λ	I
8570	6
8297	8
8228	8
8137	8
8106	10

GaBr

Occurrence. In high-frequency discharge and in absorption.

References. A. Petrikaln and J. Hochberg, *Z.P.*, **86,** 214. (1933)†.
E. Miescher and M. Wehrli, *Helv. Phys. Acta.*, **7,** 331. (1934).

SYSTEM A, λλ3616–3452

Not clearly degraded either way. (0, 0) band at λ5549·3.

SYSTEM B, λλ3568–3439

Not clearly degraded either way. (0, 0) band at λ3503·3.

SYSTEM C, λλ2874–2667

Diffuse bands. 2679 (0, 0), 2720 (0, 1), 2754 (0, 2).

GaCl

Occurrence. In high-frequency discharge and in absorption.

References. A. Petrikaln and J. Hochberg, *Z.P.*, **86,** 214. (1933)†.
E. Miescher and M. Wehrli, *Helv. Phys. Acta.*, **7,** 331. (1934)†.

SYSTEM A, λλ3469–3253

Degraded to shorter wave-lengths. Strongest bands :—

λ	I	v′, v″
3426·5	3	0, 1
3384·4	6	0, 0
3340·2	3	1, 0

SYSTEM B, λλ3430–3220

Degraded to shorter wave-lengths. Strongest bands :—

λ	I	v′, v″
3388·0	3	0, 1
3346·8	6	0, 0
3303·9	3	1, 0

GaCl (*contd.*)

SYSTEM C, λλ2700–2483

Degraded to the red. Strongest bands :—

λ	I	v′, v″
2536·5	6	0, 2
2513·3	8	0, 1
2490·6	10	0, 0
2483	8	1, 0

GaI

Occurrence. In high-frequency discharge and in absorption.

Reference. E. Miescher and M. Wehrli, *Helv. Phys. Acta.*, **7**, 331. (1934)†.

Bands 4140–3810 A. divided into two overlapping systems.

System A (0, 0) at λ3911·4, (3, 2) λ3893·0.

System B (0, 0) at λ3862·6.

GaO

Occurrence. Gallium in copper arc in air.

Transition. $^2\Sigma \rightarrow {}^2\Sigma$.

Reference. M. L. Guernsey, *P.R.*, **46**, 114. (1934)†.

(0, 1) sequence degraded to red.

λ	I	v′, v″	
4006·9	7	0, 1	
4004·8	8	1, 2	etc.

(0, 0) sequence degraded only slightly to red.

λ	I	v′, v″
3889·3	10	0, 0

(1, 0) sequence degraded to violet.

λ	I	v′, v″
3778·5	9	1, 0
3779·4	9	2, 1

GdO

Occurrence. Gadolinium chloride in oxy-hydrogen flame ; the bands do not appear well in an arc.

Appearance. Degraded to longer wave-lengths. At the blue end of the spectrum the sequences are well marked, but in the red the appearance is more confused.

Reference. G. Piccardi, *Gazz. chim. ital.*, **63**, 887. (1933)†.

The bands have been arranged into ten systems by Piccardi. The following appear from the published photographs to be the outstanding heads ; the intensities are our own estimates from these photographs.

λ	I	Syst.	v′, v″	λ	I	Syst.	v′, v″
*6223·5	6	IX	1, 1	4892·2	7	II	0, 0
*6212·1	4	X	0, 0	4816·6	5	I	1, 2
6201·2	7	IX	0, 0	4798·5	5	I	0, 1
5911·3	4	VI	0, 0	4633·3	8	I	1, 1
5818·9	9	IV	1, 1	4615·6	10	I	0, 0
*5807·2	9	IV	0, 0	4498·8	4	I	3, 2
5698·6	6	III	1, 1	4480·5	4	I	2, 1
5681·2	8	III	0, 0	4462·6	4	I	1, 0
4909·8	6	II	1, 1				

* Watson (P.R. 53, 639 (1938).) suggests that some of the sequences in the orange may be due to calcium chloride. He regards the sequences at λλ4892·2 and 4615·6 as the most sensitive for GdO.

GdO (*contd.*)

The rough measurements made by Rodden and Plantinga (*P.R.*, **45**, 280 (1934)) show practically no agreement with the above.

GeBr

Occurrence. In discharge through vapour of germanium tetra-bromide.
Appearance. Degraded to shorter wave-lengths.
Transition. Probably $^2\Pi \rightarrow {}^2\Sigma$, ground state.
Reference. W. Jevons, L. A. Bashford and H. V. A. Briscoe, *Proc. Phys. Soc.*, **49**, 532. (1937).

Bands in region 3259–2946.

Strongest heads : 2954·2 (1, 0), 2980·2 (1, 1), 2988·0 (0, 0), 3006·4 (1, 2), 3014·7 (0, 1), 3041·3 (0, 2), 3068·8 (0, 3).

GeCl

Occurrence. In discharge through vapour of $GeCl_4$.
Appearance. Degraded to shorter wave-lengths.
Transition. Probably $^2\Pi \rightarrow {}^2\Sigma$, ground state.
Reference. W. Jevons, L. A. Bashford and H. V. A. Briscoe, *Proc. Phys. Soc.*, **49**, 532. (1937).

Bands in region 3202–2848.

Strongest heads : 3059·8 (0, 1), 3007·0 (0, 2), 2971·2 (0, 1), 2936·0 (0, 0), 2891·2 (1, 0).

Also a continuum in region 2660–2510.

GeO

Occurrence. In flame surrounding arc containing GeO_2 and in discharge through mixture of oxygen and $GeCl_4$ vapour.
Appearance. Degraded to red.
Transition. Perhaps $^2\Pi \rightarrow {}^2\Sigma$.
Reference. W. Jevons, L. A. Bashford and H. V. A. Briscoe, *Proc. Phys. Soc.*, **49**, 543. (1937).

The spectrum extends from 3319 to 2442 A. The R heads of the strongest bands are listed.

λ	I	v′, v″	λ	I	v′, v″
3048·8	5	0, 5	2730·0	8	0, 1
2989·9	5	1, 5	2683·0	8	1, 1
2963·0	7	0, 4	2659·4	3	0, 0
2908·1	8	1, 4	2614·4	5	1, 0
2881·7	10	0, 3	2571·8	5	2, 0
2804·2	10	0, 2	2531·1	5	3, 0
2779·7	6	2, 3	2492·2	5	4, 0

GeS

Two band systems, both degraded to the red, have been observed in absorption.
Reference. C. V. Shapiro, R. C. Gibbs and A. W. Laubengayer, *P.R.*, **40**, 354. (1932).

Strongest bands :—

SYSTEM A, λλ3358–2709
3103·0 (0, 1), 3067·5 (1, 1), 3048·9 (0, 0), 3014·4 (1, 0).

SYSTEM B, λλ2782–2464
2657·4 (0, 2), 2653·8 (2, 3), 2615·0 (2, 2), 2594·5 (3, 2).

H_2

Occurrence. In discharge tubes containing hydrogen or water vapour. The system frequently appears when a discharge tube is first evacuated, especially if it has metal electrodes which occlude hydrogen.

Appearance. The hydrogen molecular spectrum, or "secondary" spectrum of hydrogen as it is often called, has few characteristic features, as the rotational structure is so open that there are no heads or close groups of lines to form anything resembling the usual band structure. The system is strongest in the orange but extends throughout the whole visible spectrum. Identification is rendered easier by the almost invariable presence of the strong hydrogen atomic lines, H_α 6562·79, H_β 4861·33, $H\gamma$ 4340·47 A. See Plate 4.

Reference. H. G. Gale, G. S. Monk and K. O. Lee, *Astrophys. J.*, **67**, 89. (1928).

The following are the strongest lines of the spectrum, listed as intensities 8, 9, or 10 by Gale, Monk and Lee.

λ	λ	λ	λ	λ	λ
8349·52	6135·39	5878·50	5505·52	5039·82	4709·54
8273·26	6121·79	5849·32	5499·58	5030·37	4683·82
8164·64	6098·22	5836·13	5495·96	5015·07	4662·81
7524·64	6095·96	5822·76	5481·08	5013·04	4661·40
7253·28	6080·78	5812·59	5459·60	5011·19	4631·85
7195·66	6069·99	5806·10	5434·82	5007·99	4627·99
7168·81	6063·28	5775·05	5425·89	5003·40	4617·53
6428·11	6031·90	5736·88	5419·89	4973·31	4582·59
6399·47	6027·98	5731·92	5401·05	4934·24	4579·99
6327·06	6021·27	5728·55	5388·17	4928·79	4575·88
6299·42	6018·29	5689·19	5303·10	4928·64	4572·71
6285·39	6002·82	5655·75	5291·60	4873·01	4568·13
6238·39	5994·06	5634·81	5272·30	4856·55	4554·16
6224·81	5975·44	5612·54	5266·04	4849·30	4498·11
6201·18	5949·89	5597·64	5196·37	4822·94	4212·50
6199·39	5938·62	5552·53	5084·84	4763·84	4205·10
6182·99	5931·37	5537·47	5055·09	4723·03	4177·12
6161·60	5888·17	5518·47	5041·63	4719·04	4171·31
					4069·63
					4066·88

HBr^+

Reference. F. Norling, *Z.P.*, **95**, 179. (1935).

3500 A SYSTEM, $^2\Sigma \rightarrow {}^2\Pi_i$, GROUND STATE

Widely-spaced doublet system obtained in hollow cathode discharge in hydrogen bromide. Degraded to the red.

	$^2\Sigma \rightarrow {}^2\Pi_{\frac{1}{2}}$	Heads			$^2\Sigma \rightarrow {}^2\Pi_{\frac{3}{2}}$	Heads	
v′, v″	Origins	$^QR_{12}$	Q_2	v′, v″	Origins	R_1	Q_1
0, 0?	3762	3760·3	3761·0	0, 0?	3421	3417·6	3420·5
1, 0?	3582	3581·5	3582·0	1, 0?	3272	3269·3	3271·8

HCN

INFRA-RED ABSORPTION

Occurrence. Absorption by hydrocyanic acid gas.

Reference. R. M. Badger and J. L. Binder, *P.R.*, **37**, 800. (1931).

This is the vibration-rotation spectrum. Each band shows P and R branches, but no Q branch has been observed. There is a band with origin at 7912 A. ; the R branch is stated to close up to resemble a head, probably around 7880 A. There is a similar but weaker band with origin at 8563 A.

HCl^+

Reference. M. Kulp, *Z.P.*, **67**, 7. (1931).

3500 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Pi_i$, GROUND STATE

An extensive system of bands in the region 2830–3966 A. Bands are double and possess P, Q and R branches degraded to the red. The system occurs in low pressure discharges through pure hydrogen chloride.

	$^2\Sigma \rightarrow {}^2\Pi_{\frac{1}{2}}$		$^2\Sigma \rightarrow {}^2\Pi_{\frac{3}{2}}$	
v′, v″	Origins	R Heads	Origins.	R Heads
0, 1	3966·3	3955·7	3867·8	3853·6
0, 0	3599·5	3591·6	3518·1	3507·3
1, 0	3411·9	3405·8	3338·6	3330·0
2, 0	3250·9	3245·9	3184·5	3177·3

Continua. Kulp records also a weak continuum with a maximum of intensity at 3000 A. and a second stronger continuum with a maximum at 2570–2580 A.

HNCO, isocyanic acid

Occurrence. Absorption by vapour.

Reference. Sho Chow Woo and Ta Kong Liu, *J. Chem. Phys.*, **3**, 544. (1935).

Diffuse bands λλ2565, 2545, 2528, 2513, 2505, 2495, 2477, 2465, 2445, 2434, 2415, 2400, 2385, 2370, 2357, and 2345.

Continuous absorption below 2240 A.

HNO_2 ?

Occurrence. Melvin observed the bands in absorption by a mixture of nitric oxide, nitrous oxide and water vapour. Newitt and Outridge observed a probably identical system in self-absorption from explosions and flames of carbon monoxide mixed with nitric and nitrous oxides.

Appearance. A fairly regular system of narrow headless bands.

References. E. H. Melvin and O. R. Wulf, *J. Chem. Phys.*, **3**, 755. (1935)†.
D. M. Newitt and L. E. Outridge, *J. Chem. Phys.*, **6**, 752. (1938).
H. W. Thompson, *J. Chem. Phys.*, **7**, 136. (1939).

Melvin and Wulf attributed the bands to hydrogen nitrite HNO_2, while Newitt and Outridge assigned the bands to NO_2. Thompson expressed the opinion that the two systems were not the same, and that the former are NHO_2, while the latter are due to the carrier $-NO_2$.

In the following table the wavelengths given by Newitt and Outridge (λ N & O) with intensities on a scale of 0 to 3, are compared with Melvin and Wulf's values (λ M & W) with our estimates of intensities made from the published spectrograms (on a scale of 10).

HNO_2 ? (*contd.*)

λ N & O	I	λ M & W	I	λ N & O	I	λ M & W	I
3845	1	3843	4	3485	1		
3800	0			3440	0		
3764	1			3418	3	3416	8
3726	2			3390	1	3388	4
3680	3	3681	9	3330	0		
3656	1			3305	0	3307	4
3615	0			3270	1	3278	2
3575	0			3202	0	3204	0
3545	3	3539	10	3183	0	3177	0
3513	1	3510	3				

H_2O

ATMOSPHERIC AND INFRA-RED ABSORPTION (VIBRATION-ROTATION SPECTRUM)

Occurrence. Absorption by water vapour, observed especially in solar spectrum by atmospheric absorption.

Appearance. Very complex bands, showing fairly open rotational structure, but no obvious heads.

References. W. Baumann and R. Mecke, *Z.P.*, **81**, 445. (1933)†.
K. Freudenburg and R. Mecke, *Z.P.*, **81**, 465. (1933).

The following are the origins of the bands :—

λ_0	$v'_\sigma v'_\pi v'_\delta$	λ_0	$v'_\sigma v'_\pi v'_\delta$	λ_0	$v'_\sigma v'_\pi v'_\delta$
9420	1, 2, 0	7227	1, 3, 0	5952	1, 3, 2
9060	3, 0, 0	6994	3, 1, 0	5924	1, 4, 0
8227	1, 2, 1	6524	1, 3, 1	5722	3, 2, 0
7957	3, 0, 1	6324	3, 1, 1		

The following are the strongest individual lines of each band :—

λ	I	λ	I	λ	I	λ	I
(9420)		(8227)		(7227)		(6324)	
9543·93	8	8287·94	8	7272·98	5	very weak	
9522·30	9	8282·03	7	7265·60	5		
9461·16	9	8274·35	8	7206·43	6	(5952 and 5924)	
9459·96	8	8256·52	8	7204·32	5	5941·08	5
9440·89	12	8228·31	8	7191·50	6	5932·09	5
9437·90	8	8226·96	10	7187·39	5	5924·27	4
9428·36	8	8197·70	8	7186·38	5	5919·65	7
9426·85	9	8193·11	7			5919·06	6
9386·84	9	8189·27	8	(6994)		5918·42	4
9381·22	9	8176·97	10	7016·45	3	5914·22	6
9377·74	9	8170·00	8	6989·00	3	5901·42	6
9371·58	9	8164·54	10	6886·59	3	5900·05	4
9344·05	10	8162·36	8	6977·49	3	5898·17	4
		8161·43	8	6961·27	4	5885·98	5
(9060)				6956·41	4		
9155·68	6	(7957)		6943·81	3	(5722)	
9072·01	5	7901·78	3			5737·69	1
9016·76	5			(6524)		5719·58	1
9003·80	5			6543·91	2	5692·42	1
9000·22	10			6533·95	2		
8991·88	7			6516·63	2		
				6495·86	2		
				6514·71	2		

H_2O (*contd.*)

VISIBLE EMISSION

Occurrence. Observed by Kitagawa in flame of oxygen burning in hydrogen.
Appearance. Very complex system of bands in orange and red.
Reference. T. Kitagawa, *Imp. Acad. Tokyo Proc.*, **12**, 281. (1936)†.

Kitagawa has compared the wave-lengths of these bands with the vibration-rotation spectrum, and expressed the opinion that the bands are emitted by vibrationally excited water molecules. The following are the bands as recorded.

λ	I	λ	I	λ	I	λ	I
6922·0	2	6457·5	8	6181·5	4	5880·2	6
6628·6	7	6377·1	7	6165·7	7	5861·6	3
6574·5	8	6321·6	7	5988·8	6	5806·9	3
6516·8	10	6255·1	7	5948·8	6	5715·3	1
6490·4	9	6220·0	5	5923·8	4	5683·3	2
6468·0	9	6202·6	7	5900·2	6		

FAR ULTRA-VIOLET ABSORPTION

References. S. Liefson, *Astrophys. J.*, **63**, 73. (1926)†.
G. Rathenau, *Z.P.*, **87**, 32. (1933)†.

Water vapour has a fairly sharp cut-off at 1800 A. There is a strong banded region of absorption 1780 to 1610 A., and another region of strong absorption between 1300 and 1400 A.

LIQUID WATER

Liquid water shows infra-red absorption bands at about 7750 and 9850 A., and cuts off the ultra-violet beyond 1800 A.

–OH HYDROXYL

Compounds with an OH– group, *i.e.*, alcohols, all show a strong infra-red absorption band around 9500 A.
Reference. R. M. Badger and S. H. Bauer, *J. Chem. Phys.*, **4**, 711. (1936).

He_2

Occurrence. In a mildly condensed discharge through helium at a pressure of a few centimetres of mercury.
Appearance. A number of apparently irregularly spaced bands of open rotational structure in the visible and near ultra-violet. Most of the bands are degraded to longer wave-lengths.
Transition. The helium bands can be arranged into a number of series resembling the Rydberg series of line spectra. A treatment of the analysis of the helium spectrum is beyond the scope of this work. The ground state of He_2 is unstable; the excited stable levels fall into two groups, singlets and triplets; the lowest stable levels in order from the ground state are $^3\Sigma_u$, $^1\Sigma_u$, $^3\Pi_g$, $^1\Pi_g$.
References. A very large number of papers have appeared on the molecular spectrum of helium. The data given below are based on the following early papers :—

W. E. Curtis, *P.R.S.*, **89**, 146. (1913)†.
A. Fowler, *P.R.S.*, **91**, 208. (1915).
W. E. Curtis, *P.R.S.*, **101**, 38 (1922)† ; **103**, 315. (1923).
W. E. Curtis and R. C. Long, *P.R.S.*, **108**, 513. (1925).

He$_2$ (*contd.*)

The following appear to be the most prominent heads which are degraded to the red ; the intensities are our estimates from the published spectrograms :—

λ	I	λ	I	λ	I	λ	I
6398·7	10	4648·5	10	3989·1	5	3462·4	1
6310	3	4625·6	10	3777	4	3356·4	4
5862·1	6	4545·8	5	3676·5	7	3348·0	3
5133·2	2	4157·8	4	3665·0	5	3206·4	2
5108·2	1	4002·3	4	3634	3	3200·6	2
5056·1	3						

Degraded to the violet :—

λ5733·0 9

In addition to the above well-marked heads there is a complex region of strong band structure λλ6250–5750 (there may appear to be a head at 5950 under low dispersion) and another from 4500–4400 A. with a head near 4393 when seen under low dispersion. There is also band structure from 4050–3900 A.

HfO

Occurrence. In arc containing hafnium salts.
Appearance. Degraded to the red. Long sequences.
References. W. F. Meggers, *Bur. Stand. Jour. of Research*, **1**, 151. (1928)†.
A. S. King, *Astrophys J.*, **70**, 105. (1929).

No analysis of the bands appears to have been published. The following measurements of the outstanding heads of the groups of bands (presumably heads of sequences) are by King ; the intensities, where given, are by Meggers.

λ	I	λ	I	λ	I
5698·0	10	4118·9		3840·0	–
5074·7	20	4101·2	20	3654·3	5
4252·1	25	3970·1	10	3327·8	–
				3236·1	–

Hg$_2$

Numerous papers have appeared on the emission, absorption and fluorescence bands and continua attributed to Hg$_2$. Good photographs of these have been published by Rayleigh.

References. Lord Rayleigh, *P.R.S.*, **116**, 702. (1927)†.
P.R.S., **119**, 349. (1928)†.
J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).
T. Mrozowska, *Acta. Physica Polonica*, **2**, 81. (1933).
J. Okubo and E. Matuyama, *Tohoku Union Sci. Reports*, **22**, 383. (1933)†.

λ2345 to Shorter Wave-lengths

Strong continuum commencing at about 2345 A. and fading out to shorter wave-lengths with superposed diffuse bands observed in emission, absorption and fluorescence.

Hg_2 (*ccntd.*)

Maxima of bands :—

λ	I
2342	10
2337	5
2333	1
2330	0

λ2540 TO RED

Strong continuum stretching from near the strong line λ2537 to the red with superposed diffuse bands.

In emission and fluorescence bands are observed 2659–3097 A.

In absorption the superposed bands are clearest 2613–2943 A.

λ3350

Broad continuum with maximum at 3350 A. observed in fluorescence.

λλ3650–4047 and λλ4078–4340

Emission bands have been observed in this region by Okubo and Matuyama.

λ4850

Broad continuum with maximum at 4850 A. observed in fluorescence.

Hg_2^+

Occurrence. Mercury vapour in discharge tubes, especially with Tesla coil excitation.
Appearance. Diffuse bands around 2480 A. degraded to red.
With large dispersion each band is seen to be a sequence.
Reference. L. G. Winans, *P.R.*, **42**, 800. (1932)†.

Bands as observed by Winans :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2525·4	3		2489·5	4	0, 2	2464	3	2, 0
2518·0	3		2482	5	0, 1	2458·0	3	3, 0
2509·4	2		2476·1	10	0, 0	2449·5	1	
2495·6	3	0, 3	2469·5	5	1, 0			

HgBr or $HgBr_2$

Occurrence. Three systems have been observed in a discharge through mercury bromide vapour by Wieland, and some of these have also been observed with modified intensity distribution in fluorescence of $HgBr_2$.
Reference. K. Wieland, *Helv. Phys. Acta.*, **2**, 46. (1929)†.

SYSTEM λλ2665–2471

Degraded to shorter wave-lengths. Heads of strong sequences :—

λ	I	Sequence	λ	I	Sequence
2627·8	4	0, 3	2575·1	7	1, 0
2615·3	7	0, 2	2560·2	6	2, 0
2602·7	8	0, 1	2545·5	5	3, 0
2590·2	6	0, 0	2531·5	3	4, 0

HgBr or $HgBr_2$ (*contd.*)

SYSTEM λλ2900–2650

Degraded to shorter wave-lengths. Heads of strong groups of bands at λλ2906·5, 2898·8, 2891·0, 2883·7, 2875·5, 2868·1, 2853·3.

SYSTEM 5000–3200 A.

Diffuse bands, perhaps shaded to red.

HgCl or $HgCl_2$

Occurrence. Three systems have been observed by Wieland with mercuric chloride in a heated discharge tube. Bands have also been observed, with modified intensity distribution, in fluorescence of $HgCl_2$.

References. K. Wieland, *Helv. Phys. Acta.*, **2**, 46. (1929)†.
Nature, **139**, 590. (1937).

SYSTEM λλ2637–2379

Degraded to shorter wave-lengths. Heads of strong sequences :—

λ	I	Sequence	λ	I	Sequence
2609·1	2	0, 5	2516·5	7	0, 0
2590·5	3	0, 4	2495·4	7	1, 0
2572·0	4	0, 3	2474·6	5	2, 0
2553·4	6	0, 2	2454·6	3	3, 0
2535·0	7	0, 1	2435·1	1	4, 0

SYSTEM 2800–2700 A.

Degraded to shorter wave-lengths. Heads of strong groups of bands, λλ 2813·2, 2805·4, 2792·1, 2783·8, 2742·2, 2740·9 and 2719·5.

SYSTEM 6000–3100 A.

Diffuse bands, probably degraded to the red.

HgH

References. E. Hulthén, *Z.P.*, **32**, 32. (1925).
E. Hulthén, *Z.P.*, **50**, 319. (1928).
R. Rydberg, *Z.P.*, **73**, 74. (1931).

4017 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$, ground state

A wide-spaced doublet system with bands degraded to the violet, each showing P, Q and R branches. Obtained in discharges through mercury vapour and hydrogen.

P Heads

	$^2\Pi_{\frac{1}{2}} \rightarrow {}^2\Sigma$			$^2\Pi_{\frac{3}{2}} \rightarrow {}^2\Sigma$	
v′, v″	λ	I	v′, v″	λ	I
0, 3	4520	2	0, 2	3785	2
0, 2	4394	4	0, 1	3647	3
0, 1	4219	7	0, 0	3500	5
0, 0	4017	10	1, 0	3274	3
1, 1	3900	2	2, 1	3200	2
1, 0	3728	4			

HgH (*contd.*)

2950 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$

Bands with double P and R branches degraded to the red.

v′, v″	Origins	R_1 Head	R_2 Head
0, 1	3059·8	3057·6	3057·8
0, 0	2951	2949·5	2949·7

2807 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$

Two bands are observed degraded to the red. Double P and R branches.

v′, v″	Origins	R_1 Head	R_2 Head
0, 1	2904		
0, 0	2808	2807·3	2807·0

2700 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$

Band with double P and R branches degraded to the red.

v′, v″	Origin	R_2 Head
0, 0	2699	2696

HgH$^+$

Reference. T. Hori, *Z.P.*, **61**, 481. (1930)†.

2264 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$, ground state

An extensive system of bands degraded to the red, each with a single P and single R branch. Occurs in discharges through hydrogen and mercury vapour where ionisation is favoured as in hollow cathode.

v′, v″	R Heads	I
0, 0	2263·9	10
1, 1	2286·7	5
0, 1	2367·3	9
1, 2	2388·1	8
2, 3	2413·3	3
0, 2	2474·7	4
1, 3	2493·9	7

HgI and **HgI$_2$**

Occurrence. In emission in discharge tubes, including high-frequency discharge, and in fluorescence. The violet bands have also been observed in active nitrogen.

References. K. Wieland, *Helv. Phys. Acta.*, **2**, 46. (1929).
K. Wieland, *Z.P.*, **76**, 801. (1932).
A. Terenin, *Z.P.*, **44**, 713. (1927).
T. S. Subbaraya, B. N. Rao, and N. A. N. Rao, *Indian Acad. Sci. Proc.*, **5A**, 365. (1937).

VIOLET SYSTEM, λλ4488–4127

Appearance. Diffuse bands shaded to the red.

The following are the maxima of the strong bands from Subbaraya, Rao and Rao, λλ4456·0, 4430·0, 4423·6, 4413·1, 4381·6, 4320·8, 4309·9 and 4271·3.

λλ3084–2853 SYSTEM

Appearance. Degraded to shorter wave-lengths. This is a complex system and has been attributed to HgI$_2$.

HgI and HgI$_2$ (*contd.*)

The following are the heads of the strongest bands as given by Wieland : λλ3072·6, 3061·9, 3061·0, 3051·5, 3049·5, 3041·4, 3007·3, 2998·4, 2979·0, 2970·8 and 2920·9.

λλ2800–2650 SYSTEM

Degraded to the violet. Probably due to HgI. No measurements available.

HgO ?

Reference. J. M. Walter and S. Barratt, *P.R.S.*, **122,** 201. (1929).

Walter and Barratt record absorption bands λλ2943–2739 using mercury vapour and oxygen. The assignment to HgO is uncertain.

HgS

Reference. P. K. Sen Gupta, *P.R.S.*, **143,** 438. (1933–4).

Continuous absorption in three regions beginning at λλ4450, 3100 and 2250.

I$_2$

A large number of papers have been published on the spectrum of iodine. The most readily observed system is the well-known visible absorption bands which are responsible for the violet colour of the vapour. All the band systems of iodine are composed of a very large number of close narrow bands, and distinctive features are lacking.

VISIBLE SYSTEM

Occurrence. This system has been studied principally in absorption. Bands have been observed in fluorescence, and Uchida has obtained the system in emission by the heated vapour. There seems to be no obvious reason why the bands should not appear readily in emission in other sources.

Appearance. Degraded to longer wave-lengths. Numerous regularly spaced bands extending from the far red to the absorption limit at about 5000 A. The system is too extensive to publish wave-lengths, but a spectrogram is shown in Plate 6.

Transition. $0^+ \rightleftharpoons {}^1\Sigma^+$, ground state.

References. R. Mecke, *Ann. Physik.*, **71,** 104. (1923).
F. W. Loomis, *P.R.*, **29,** 112. (1927).
Y. Uchida, *Inst. Phys. Chem. Res. Tokyo Sci. Papers*, No. 651, p. **71.** (1936)†.

ULTRA-VIOLET SYSTEMS

Occurrence. Bands beyond 2150 A. appear readily in absorption, and by heating the vapour and using greater thicknesses absorption bands have been observed to 3400 A. Bands are also observed in fluorescence.

References. P. Pringsheim and B. Rosen, *Z.P.*, **50,** 1. (1928).
M. Kimura and M. Miyanishi, *Inst. Phys. Chem. Res. Tokyo Sci. Papers*, **10,** 33. (1929)†.
E. Hirschlaff, *Z.P.*, **75,** 325. (1932).
W. E. Curtis and S. F. Evans, *P.R.S.*, **141,** 603. (1933).
D. T. Warren, *P.R.*, **47,** 1. (1935).

INFRA-RED

Absorption bands from 8300 A. to 9300 A. have been observed by Brown.

Reference. W. G. Brown, *P.R.*, **38,** 1187. (1931).

IBr

Occurrence. In absorption.

Appearance. Degraded to longer wave-lengths. Waves of closely-spaced bands extending from the green to the red have been arranged into two systems, and there is a third system in the near infra-red. Cordes gives a long table of wave-lengths of the visible bands, but no intensities are available.

References. R. M. Badger and D. M. Yost, *P.R.*, **37,** 1548 (L). (1931).
H. Cordes, *Z.P.*, **74,** 34. (1932).
W. G. Brown, *P.R.*, **42,** 355. (1932).

ICl

Occurrence. In absorption.

Appearance. Degraded to the red. An extensive system of closely-spaced bands from the yellow green to the near infra-red. The strongest bands apparently form two long progressions in the orange to red. Under large dispersion the heads are not very obvious. Wave-lengths and some photographs have been published by Curtis and Patkowski.

References. O. Darbyshire, *P.R.*, **40,** 366. (1932).
G. E. Gibson and H. C. Ramsperger, *P.R.*, **30,** 598. (1927).
W. E. Curtis and J. Patkowski, *Phil. Trans. Roy. Soc.*, **232,** 395. (1934)†.

IO ?

METHYL IODIDE FLAME BANDS

Occurrence. In flame of methyl iodide (mixed with methyl alcohol or common gas to assist the combustion) ; the bands are emitted by the green region just above the inner cone.

Appearance. Degraded to the red.

Reference. W. M. Vaidya, *Indian Acad. Sci. Proc.*, **6A,** 122. (1937)†.

The bands are provisionally attributed to iodine monoxide, IO. They form two systems. The following are the strong bands :—

SYSTEM A

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4780·5	4	4, 6	4621·1	6	2, 3	4445·9	5	0, 0
4757·8	4	3, 5	4583·0	10	1, 2	4384·3	4	1, 0
4725·6	6	2, 4	4549·2	5	0, 1	4353·7	5	—
4686·2	8	1, 3	4485·0	7	1, 1	4267·8	4	3, 0

SYSTEM B

λ	I	v′, v″
5686·0	4	0, 4
5522·6	4	1, 4
5488·9	5	0, 3
5301·8	6	0, 2
5125·9	6	0, 1
4960·4	4	0, 0
4838·5	8	1, 0

In_2

Occurrence. In absorption and fluorescence of indium vapour.
Reference. R. Wajnkranc, *Z.P.*, **104**, 122. (1936–7).

The following are the chief features of the absorption spectrum :—
Diffuse broad bands maxima λλ3818, 3734, 3680.
3548–3523 A. A group of narrow bands degraded to the red.
3259 A. A group of narrow bands to the red of the In line.
2340 A. A group of narrow bands on the shorter wave-length side of the In line.

InBr

Three systems have been observed in emission in a high-frequency discharge and in absorption.

References. A. Petrikaln and J. Hochberg, *Z.P.*, **86**, 214. (1933)†.
M. Wehrli and E. Miescher, *Helv. Phys. Acta*, **7**, 298. (1934)†.

System A, λλ3852–3641

Some bands degraded slightly to shorter wave-lengths. Strongest bands :—

λ	I	v′, v″
3789·8	4	0, 1
3758·5	8	0, 0
3727·2	4	1, 0

System B, λλ3726–3568

Some bands degraded slightly to red. Strongest bands :—

λ	I	v′, v″
3681·1	9	1, 2
3651·2	10	0, 0
3596·7	6	3, 1
3595·3	6	2, 0

System C, λλ3083–2852

Single progression of diffuse bands, 2852 (0, 0), 2896 (0, 1), 2926 (0, 2), 2956 (0, 3), etc.

InCl

Three systems have been observed in emission in a high-frequency discharge, and also in absorption.

References. A. Petrikaln and J. Hochberg, *Z.P.*, **86**, 214. (1933)†.
M. Wehrli and E. Miescher, *Helv. Phys. Acta*, **7**, 298. (1934)†.
E. Miescher and M. Wehrli, *Helv. Phys. Acta*, **6**, 256. (1934).

System A, λλ3640–3471

Degraded to shorter wave-lengths. Strongest bands :—

λ	I	v′, v″	λ	I	v′, v″
3599·2	6	0, 0	3554·0	4	2, 1
3596·5	2	1, 1	3514·6	2	2, 0
3556·2	5	1, 0	3513·0	3	3, 1

InCl (*contd.*)

SYSTEM B

Degraded to shorter wave-lengths. Q heads of strongest bands,

λ	I	v′, v″
3499·0	8	0, 0
3458·5	5	1, 0
3456·3	4	2, 1
3419·3	3	2, 0

SYSTEM C

Degraded to the red. Strongest bands at λλ2672·1 (0, 0), 2694·7 (0, 1), 2717·5 (0, 2), 2740·6 (0, 3) and λλ2661·3 (1, 0), 2683·7 (1, 1) in absorption only.

InH

Reference. B. Grundström, *Nature*, **141**, 555. (1938).

5914 A. SYSTEM, $^1\Pi \rightarrow {}^1\Sigma$

Band degraded to the violet with single P, Q and R branches. Obtained in emission from an arc between indium and carbon electrodes in hydrogen at high pressure.

v′, v″	Origin		Heads	
0, 0	5913·8	5913·3	5940·7	6185·1

5689 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$

Bands degraded to the red with single P and R branches.

v′, v″	Origins
0, 0	5688·6
0, 1	6190·9

Further bands appear in the red and infra-red.
Heads degraded to the red.

λ	λ
5640·4	6255·5
5945·8	6447·1
6070·9	7027
6108·3	

InI

Two overlapping systems λλ4293–3948 with (0, 0) bands at 4098·5 and 3993·4 A. have been observed in a high-frequency discharge and in absorption. There is also a continuum with maximum at about 3173 A.

Reference. M. Wehrli and E. Miescher, *Helv. Phys. Acta*, **7**, 298. (1934)†.

InO

Bands 4500–4100 A. have been observed in an arc ; the strong bands are stated to be degraded to the red ; no wave-lengths are available.

Reference. M. L. Guernsey, *P.R.*, **46**, 114. (1934).

K_2

Strong band systems attributed to K_2 have been observed in the far red, the near red and the blue, and weaker systems are reported in the ultra-violet.

Far Red System

Occurrence. In absorption.
Appearance. Numerous bands in the region λλ8840–7728 degraded to longer wave-lengths.
Transition. $B\,^1\Sigma \leftarrow A\,^1\Sigma$, ground state.
References. J. C. McLennan and D. S. Ainslie, *P.R.S.*, **103**, 304. (1923)†.
W. O. Crane and A. Christy, *P.R.*, **36**, 421. (1930).

Crane and Christy record a long list of heads, but no intensities. The following wave-lengths may assist the identification :—8702·0 (0, 2), 8634·4 (0, 1), 8566·3 (0, 0), 8515·7 (1, 0), 8468·2 (2, 0). McLennan and Ainslie record maxima at λλ8602, 8547, 8492, 8447, 8407, 8375, 8309, 8266 and 8213.

Near Red System

Occurrence. In absorption, in fluorescence and in magnetic rotation.
Appearance. Numerous bands in the region λλ6922–6280, degraded to the red.
Transition. $C\,^1\Pi \leftarrow A\,^1\Sigma$, ground state.
References. W. R. Fredrickson and W. W. Watson, *P.R.*, **30**, 429. (1927).
W. O. Crane and A. Christy, *P.R.*, **36**, 421. (1930).

Strongest heads :—

λ	I	v′, v″	λ	I	v′, v″
6629·8	5	1, 4	6473·9	10	1, 0
6622·8	6	0, 3	6443·2	8	2, 0
6583·4	9	0, 2	6413·0	7	3, 0
6544·1	8	0, 1	6383·7	5	4, 0
6512·6	5	1, 1			

Blue System

Occurrence. In absorption.
Appearance. Degraded to the red.
Transition. $D\,^1\Sigma \leftarrow A\,^1\Sigma$, ground state.
Reference. H. Yamamoto, *Jap. J. of Phys.*, **5**, 153. (1929).

Strongest heads :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4442·8	7	0, 5	4349·7	8	2, 1	4299·3	10	5, 0
4425·3	8	0, 4	4338·4	9	3, 1	4288·5	8	6, 0
4407·8	7	0, 3	4321·2	9	3, 0	4277·8	8	7, 0
4378·6	8	1, 2	4310·2	8	4, 0	4267·2	7	8, 0
4361·1	7	1, 1						

Other Systems

H. Yoshinaga (*Phys. Math. Soc. Japan Proc.*, **19**, 847 (1937)) has reported absorption bands in the region λλ4160–3480.

B. K. Chakraborti (*Indian J. Phys.*, **10**, 155 (1936)) has reported absorption bands associated with each doublet of the principal series ; these bands only appear at high temperatures.

KCd

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd). Heads $\lambda\lambda$4191, 4172.

KCs

Reference. J. M. Walter and S. Barratt, *P.R.S.*, **119**, 257. (1928).

Diffuse absorption band at λ5387.

KH

References. G. M. Almy and C. D. Hause, *P.R.*, **42**, 242. (1932).
T. Hori, *Mem. Ryojun Coll. Eng.* **6**, **1**, 33. (1933).

5100 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$, GROUND STATE

System of the many-lined type with weak R-heads degraded to the red. The system is readily obtained in absorption from a mixture of hydrogen and potassium vapour and in emission from a potassium arc in hydrogen or from discharges through a mixture of hydrogen and potassium vapour.

Origins of strongest bands :—

v′, v″	λ_0	v′, v″	λ_0
2, 2	5613·4	5, 0	4870·2
3, 2	5528·7	6, 0	4802·8
4, 2	5444·7	7, 0	4736·7
5, 2	5362·3	8, 0	4672·2
3, 1	5259·0	9, 0	4608·9
4, 1	5183·3	10, 0	4547·5
5, 1	5108·3	11, 0	4487·7
6, 1	5034·0	12, 0	4429·7
7, 1	4960·6	13, 0	4373·5

KHg

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd). Heads $\lambda\lambda$6188, 6150, 4113 and 3988.

KRb

Reference. J. M. Walter and S. Barratt, *P.R.S.*, **119**, 257. (1928).

Diffuse absorption band at λ4959.

KZn

Diffuse band, degraded to the violet, observed in absorption by Barratt (see CsCd). Head λ4147.

LaO

Strong systems attributed to lanthanum oxide have been observed in the red, the yellow, and the blue, and there is also a weaker system in the near ultra-violet.

Occurrence. In arcs fed with lanthanum salts.

References. W. F. Meggers and J. A. Wheeler, *Bur. Stand. J. Res.*, **6**, 239. (1931)†.
W. Jevons, *Proc. Phys. Soc.*, **41**, 520. (1929).
F. A. Jenkins and A. Harvey, *P.R.*, **39**, 922. (1931).

RED SYSTEM, $\lambda\lambda$6867–9729

Appearance. Degraded to longer wave-lengths. Marked sequences.

Transition. A $^2\Pi \rightarrow$ X $^2\Sigma$, ground state.

LaO (*contd.*)

The following are the strongest heads at the beginning of the main sequences. Measurements are by Meggers and Wheeler; intensities have been reduced to a scale of 10. The two sub-bands due to the doubling of the $^2\Pi$ state are denoted by i and ii.

λ	I	v′, v″	λ	I	v′, v″
6994·5	1	1, 0 i R	7877·2	6	0, 0 ii R
7011·2	2	1, 0 i Q	7910·5	8	0, 0 ii Q
7023·6	1	2, 1 i R	7912·3	3	1, 1 ii R
7040·8	2	2, 1 i Q	7944·9	6	1, 1 ii Q
7054·8	1	3, 2 i R	7947·9	2	2, 2 ii R
7070·8	2	3, 2 i Q	7979·7	5	2, 2 ii Q
7379·8	8	0, 0 i R	8406·0	1	0, 1 ii R
7403·5	10	0, 0 i Q	8443·3	2	1, 2 ii R
7411·3	5	1, 1 i R	8453·5	3	0, 1 ii Q
7434·3	6	1, 1 i Q	8481·0	1	2, 3 ii R
7442·9	4	2, 2 i R	8489·9	3	1, 2 ii Q
7465·2	5	2, 2 i Q	8526·6	3	2, 3 ii Q

YELLOW SYSTEM, λλ6450–5015

Appearance. Degraded to the red. Marked sequences. The bands show close double heads (R_1 and R_2) separation about 2·5 A.
Transition. $B\,^2\Sigma \rightarrow X\,^2\Sigma$, ground state.

The following measurements of the first of the close double heads are by Jevons. Intensities, where given, are based on Meggers and Wheeler's reduced to a scale of 10. Only the prominent heads are given.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5178·3		2, 0	5599·9	10	0, 0	5920·7	4	2, 3
5202·7		3, 1	5626·0	5	1, 1	6157·4	0	0, 2
5380·4	1	1, 0	5652·3	3	2, 2	6185·7	1	1, 3
5405·6	2	2, 1	5866·3	3	0, 1	6214·1	1	2, 4
5430·9	2	3, 2	5893·4	4	1, 2	6242·6	2	3, 5

BLUE SYSTEM, λλ4348–4622

Appearance. Degraded to the red. Two strong and some weaker sequences of very close (separation 0·1 A.) double-headed bands.
Transition. $C\,^2\Pi \rightarrow X\,^2\Sigma$, ground state.

The following are the bands forming the heads of the sequences. Measurements compiled from Jevons, and Meggers and Wheeler. Intensities, where given, are based on those given by Meggers and Wheeler reduced to scale of 10. The two sub-bands due to the $^2\Pi$ level are denoted by i and ii.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4348·2			4379·6	4	2, 2 i	4433·0	6	3, 3 ii
4352·2			4383·4	3	3, 3 i	4580·7	1	0, 1 ii
4356·3			4418·1	10	0, 0 ii	4585·0	1	1, 2 ii
4371·9	8	0, 0 i	4423·1	8	1, 1 ii	4589·4	1	2, 3 ii
4375·7	6	1, 1 i	4428·0	6	2, 2 ii	4593·8	1	3, 4 ii

LaO (*contd.*)

ULTRA-VIOLET SYSTEM, λλ3457–3709

Appearance. Degraded to shorter wave-lengths.
Transition. Uncertain. The final state is probably $X^2\Sigma$.
The following are the strong bands as listed by Jevons :—

λ	I	λ	I
3709·6	3	3604·6	6
3614·9	6	3566·2	5
3611·5	6	3560·9	4
3608·1	6	3556·3	3

Li_2

Occurrence. Two systems have been observed, in the red and in the blue-green, in absorption, magnetic rotation, and in fluorescence.

RED SYSTEM

Appearance. Degraded to longer wave-lengths.
Transition. $^1\Sigma \rightarrow {}^1\Sigma$, ground state.
Reference. K. Wurm, *Z.P.*, **59**, 35. (1930).
Strong bands :—

λ	I	v′, v″
7690·3	8	0, 2
7309·8	8	0, 1
7177·4	8	1, 1
7003·7	8	1, 0
6883·9	10	2, 0
6768·7	8	3, 0
6659·3	8	4, 0

BLUE-GREEN SYSTEM

Appearance. Degraded to the red.
Transition. $^1\Pi \rightarrow {}^1\Sigma$, ground state.
Reference. A. McKellar, *P.R.*, **44**, 155. (1933).
Strongest bands :—

λ	v′, v″
4985·6	0, 1
4901·0	0, 0
4838·3	1, 0
4778·6	2, 0

LiCs

Bands, degraded to the red, have been observed in absorption by a mixture of lithium and cæsium vapours.

References. J. M. Walter and S. Barratt, *P.R.S.*, **119**, 257. (1928).
W. Weizel and M. Kulp, *Ann. Physik*, **4**, 971. (1930).

Strongest bands : λλ6255, 6217, 6180, 6146 and 6116.

LiH

References. G. Nakamura, *Z.P.*, **59,** 218. (1930).
F. H. Crawford and T. Jorgensen, *P.R.*, **47,** 932. (1935).

3900 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$, ground state

This system presents a many-lined appearance which recalls the spectrum of molecular hydrogen. Weak R heads degraded to the red are formed near the origins, but are not obvious on casual inspection. The system is readily obtained in absorption from a mixture of hydrogen and lithium vapour and in emission from a lithium arc in hydrogen or a discharge through a mixture of hydrogen and lithium vapour.

Origins of the strongest bands :—

v′, v″	λ_0	v′, v″	λ_0
0, 2	4297·5	3, 0	3720·2
1, 2	4245·2	4, 0	3672·0
2, 2	4189·5	5, 0	3623·3
1, 1	4020·7	6, 0	3574·6
2, 1	3970·7	7, 0	3526·4
3, 1	3918·5	8, 0	3478·8
2, 0	3767·2	9, 0	3432·2

TRIPLET SYSTEM ?

Crawford and Jorgensen note a close grouping of lines in the far red which they suggest belong to another system.

LiK

References. See LiCs.

Absorption bands degraded to the red. Strongest bands λλ5838·7, 5769·3, 5724·0, 5700·0, 5658·0 and 5620·0.

LiRb

References. See LiCs.

Absorption bands degraded to the red. Strongest bands λλ5815·5, 5778·0, 5743·0 and 5712·5.

LuO

Occurrence. Lutecium salts in arc.

Appearance. Degraded to the red. Head of strong (0, 0) sequence at λ4661·7 ; a few weaker bands of the (0, 1) and (1, 0) sequences have been observed.

Reference. W. W. Watson and W. F. Meggers, *Bur. Stand. J. Res.*, **20,** 125. (1938)†.

The following are the strongest heads at the beginning of the (0, 0) sequence :—

λ	I	v′, v″
4661·7	10	0, 0
4672·3	9	1, 1
4684·2	8	2, 2
4695·5	6	3, 3
4708·0	4	4, 4

Mg_2

Reference. H. Hamada, *Phil. Mag.*, **12**, 50. (1931)†.

Hamada has studied the emission by magnesium in a hollow cathode. The magnesium lines, especially λ2852, are broadened, and the spectrum shows patches of continuum and flutings which are attributed to incipient formation of Mg_2 molecules.

MgBr

Occurrence. In absorption, in flames and probably in arcs.
Appearance. Degraded to shorter wave-lengths.
References. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).
C. M. Olmsted, *Zeit. f. wissen. Photographie*, **4**, 255. (1906).

Bands as listed by Walters and Barratt; each recorded head is probably a sequence. Only the two strongest heads were observed by Olmsted in a flame.

λ	I
3934	0
3918	2
3881	10*
3864	10
3841	0
3821	2*
3819	2

* Narrow band not clearly degraded.

MgCl

Occurrence. Magnesium chloride in arc (best in inert gas at reduced pressure using nickel or copper electrodes).
Appearance. Degraded to violet. Marked sequences.
Transition. Perhaps $^2\Sigma \rightarrow {}^2\Sigma$, ground state.
Reference. A. E. Parker, *P.R.*, **47**, 349. (1935).
No intensities given.

λ	
3842·2	P_1 head of 0, 1 sequence.
3778·9	P_1 head of 0, 0 band and sequence.
3775·7	P_2 head of 0, 0 band.
3772·0	P_1 head of 1, 1 band.
3770·2	P_2 head of 1, 1 band.
3708·4	P_1 head of 1, 0 sequence.

There is also a weaker system, with the head of the (0, 0) sequence at λ3860·5 degraded to shorter wave-lengths.

MgF

There are three systems of bands in the ultra-violet due to MgF, a strong system λλ3686–3468, a weak system λλ2742–2649, and another system near 2275 A.

Strong System, λλ3686–3468

Occurrence. Carbon arc fed with MgF_2.

MgF (*contd.*)

Appearance. Degraded to shorter wave-lengths. Well-marked double-headed sequences.
Transition. A $^2\Pi \rightarrow {}^2\Sigma$, ground state.
Reference. S. Datta, *P.R.S.*, **99**, 436. (1921)†.
Heads of sequences :—

λ	I	Sequence
3685·8	5	0, 1
3682·8		
3594·2	10	0, 0
3592·8		
3503·4	4	1, 0
3502·4		

WEAK SYSTEM, λλ2742–2649

Occurrence. Carbon arc fed with MgF_2.
Appearance. Degraded to shorter wave-lengths. Well-marked sequences of single-headed bands.
Transition. B $^2\Sigma \rightarrow {}^2\Sigma$, ground state.
Reference. W. Jevons, *P.R.S.*, **122**, 211. (1929)†.
Strongest bands :—

λ	I	v′, v″
2741·6	2	0, 1
2689·3	5	0, 0
2686·5	4	1, 1
2636·5	3	1, 0

λ2275 SYSTEM

Occurrence. In absorption.
Appearance. Degraded to shorter wave-lengths. A single compact sequence.
Transition. C $^2\Pi \rightarrow {}^2\Sigma$, ground state.
Reference. F. A. Jenkins and R. Grinfeld, *P.R.*, **43**, 943. (1933).
Strongest heads, λλ2276·7, 2275·9, 2275·3 and 2274·9.

Note.—There is a strong absorption system in this region due to AlF.

MgH

Six systems have been reported for MgH, of which the 5211 A. and 2430 A. systems are the most prominent.

References. A. Guntsch, *Dissertation, Stockholm.* (1939).
W. W. Watson and P. Rudnick, *Astrophys. J.*, **63**, 20. (1926).
W. W. Watson and P. Rudnick, *P.R.*, **29**, 413. (1927).

5211 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$, ground state

Bands degraded to the violet with P, Q and R branches consisting of narrow doublets. Obtained in emission in the magnesium arc in hydrogen, in discharge tubes containing magnesium vapour and hydrogen and in absorption in spectra of sun spots.

MgH (*contd.*)

v′, v″	Heads P	Q
0, 2	6083	
0, 1	5621·4	5609·5
1, 2	5568·3	5549·9
2, 3	5516·4	
0, 0	5211·0	5186·4
1, 1	5182·3	
2, 2	5155·2	
1, 0	4845	

References. R. W. B. Pearse, *P.R.S.*, **122, 442.** (1929).
A. Guntsch, *Z.P.*, **93,** 534. (1935).
L. A. Turner and W. T. Harris, *P.R.*, **52,** 626. (1937).

2430 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$, ground state

Bands degraded to the violet similar in appearance to the above bands, except that the doubling is much smaller. They occur under similar circumstances.

v′, v″	Heads P	Q
0, 1	2515·3	2510·5
1, 2		2495
0, 0	2429·2	2424·1
1, 1		2413·0
1, 0		2332

Reference. A. Guntsch, *Z.P.*, **87,** 312. (1934).

4550 A. SYSTEM, $^2\Pi \rightarrow {}^2\Pi$

Weak bands of headless type with P and R branches composed of narrow doublets.

	Origins
0, 0	4553
1, 1	4535

Reference. A. Guntsch, *Z.P.*, **104,** 584. (1937).

4405 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Pi$

Band with two strong heads degraded to the violet.

v′, v″	Q_1	Heads Q_2	P_1	P_2
0, 0	4371·9	4373·0	4404·5	4404·6

2590 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$

Band with P and R branches. The R branch shows a peculiar crowding of lines at 2590·4 which gives an intensity maximum without forming a head. Obtained in absorption and emission.

v′, v″	Origin
0, 0	2597

MgH (*contd.*)

2348 A. SYSTEM

A band with a Q branch obtained under the same conditions as the above. Assignment somewhat doubtful.

MgH^+

References. A. Guntsch, *Dissertation, Stockholm.* (1939).
A. Guntsch, *Z.P.*, **107**, 420. (1937).
R. W. B. Pearse, *P.R.S.*, **125**, 157. (1929).

2806 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$

An extensive system of bands each with a single P and single R branch. Obtained from a magnesium arc in hydrogen at low pressures or from a discharge tube containing magnesium vapour and hydrogen under conditions favouring ionisation.

Origins of Strongest Bands

v′, v″	λ	v′, v″	λ
0, 4	3388·8	0, 0	2805·8
0, 3	3232·5	1, 0	2720·5
0, 2	3083·0	2, 0	2641·3
0, 1	2940·6	3, 0	2567·9
1, 1	2847·0	4, 0	2499·7

$^1\Pi \rightarrow {}^1\Sigma$

Bands degraded to the red, each with single P, Q and R branches.

v′, v″	R Heads	Q Heads
0, 2	2142	2144
0, 3	2211	2214
0, 4	2284	2285
0, 5	2357	2358

MgI

Occurrence. In absorption.
Reference. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).

The following measurements are by Walters and Barratt. Each band may be the head of a sequence. The letters R and V indicate that the band is degraded to longer or shorter wave-lengths.

λ	I	λ	I	λ	I
4110 V	10	3927 R	2	3432 V	0
4027 V	1	3902 R	2	3405 V	0
4001 R	1	3657 V	1	3396 V	0
3983 V	10	3628 V	1	3380 V	0
3951 R	10	3602 V	1	3358 V	0

Olmsted (*Zeit. f. wissen. Photographie,* 4, 255 (1906)) observed the head at 4110 A. in a flame source.

MgO

Occurrence. In magnesium arc burning in air.
Appearance. Degraded to violet. Single-headed. Two systems of bands, one in the red and a stronger one in the green.
Reference. P. C. Mahanti, *P.R.*, **42**, 609. (1932)†.

MgO (*contd.*)

RED SYSTEM

Only a few of the strongest heads are listed below :—

λ	I	v′, v″
6581·0	3	0, 2
6311·7	4	0, 1
6246·4	3	1, 2
6060·3	6	0, 0
5775·5	5	1, 0
5726·3	3	2, 1
5518·8	4	2, 0
5475·9	3	3, 1
5285·7	3	3, 0

GREEN SYSTEM

Some of the weak bands have been omitted.

λ	I	v′, v″	λ	I	v′, v″
5206·0	4	0, 1	4985·9	8	2, 2
5192·0	4	1, 2	4974·5	7	3, 3
5177·4	3	2, 3	4962·1	6	4, 4
5162·5	3	3, 4	4949·5	5	5, 5
5146·8	3	4, 5	4935·3	4	6, 6
5007·3	10	0, 0	4923·9	3	7, 7
4996·7	9	1, 1			

MnBr or $MnBr_2$

Occurrence. Manganous bromide in high-frequency discharge.

Reference. P. Mesnage, *Thesis for doctorate, Paris.* (1938).

The following are the strongest heads ; the letters R, V or M indicate that the band is degraded to longer or shorter wave-lengths or is headless.

λ	I	λ	I
5086·9 V	8	3866·0 V	4
5081·0 M	15	3823·5 V	4
5075·0 M	9	3772·1 V	4
5072·5 M	7	3720·5 V	6
4993·5 R	10		

MnCl or $MnCl_2$

Occurrence. Manganous chloride in high-frequency discharge.

Reference. P. Mesnage, *C.R. Acad. Sci. Paris,* **204,** 761 (1937) ; and *Thesis for doctorate, Paris.* (1938).

VISIBLE REGION

The following are the strongest heads ; the letters R, V or M indicate that the band is degraded to longer or shorter wave-lengths or is headless :—

λ	I	λ	I	λ	I
5043·5 V	5	5025·3 M	5	4517·3 M	4
5038·8 M	10	5018·9 R	6	4409·5 M	4
5033·7 M	5	5013·0 R	4	4341·2 M	5
5026·3 M	5	4977·5 M	5	4331·1 M	4

MnCl or $MnCl_2$ (*contd.*)

ULTRA-VIOLET SYSTEM

Appearance. Degraded to shorter wave-lengths; marked sequences of close double-headed bands. These bands are definitely due to the diatomic molecule MnCl. Outstanding heads.

λ	I	v′, v″
3770·6	3	0, 1 head of sequence
3717·0	5	0, 0 head of long sequence
3712·8	5	1, 1
3661·3	5	1, 0 head of long sequence
3658·2	5	2, 1

MnH

Reference. R. W. B. Pearse and A. G. Gaydon, *Proc. Phys. Soc.*, **50**, 201. (1938)†.
Occurrence. The spectrum of MnH has been observed in high-tension arc between manganese electrodes in a hydrogen flame and in a discharge tube containing hydrogen and manganese vapour. A. Heimer has observed the spectrum in emission and absorption using a furnace.

5677 A. SYSTEM, $^7\Pi \rightarrow {^7\Sigma}$

Bands degraded to the violet of very complex structure.

	Heads			
v′, v″	λ	I	λ	I
0, 1	6237	2		
0, 0	5677	10	5720	2
1, 0	5172	4		

4800 A. SYSTEM

Strong band degraded to the red. Very complex in structure.

	Heads			
v′, v″	λ	I	λ	I
0, 0 ?	4741	4	4794	5

4500 A. SYSTEM

Open band structure degraded to the red. The strong lines fall into five branches, which close up to a weak head about λ4480.

Head	
λ	I
4480	1

MnO

Occurrence. In flame surrounding manganese arc in air.
Appearance. Degraded to red. Well-marked sequences.

MnO (*contd.*)

Reference. A. K. S. Gupta, *Z.P.*, **91,** 471. (1934)†.

Only the strong bands are listed below. Intensities are our own estimates from Gupta's published photographs. S denotes head of sequence.

λ	I	v′, v″
6523·8	3	2, 5
6203·2	6	2, 4
6175·9	7	1, 3
6154·9	7	0, 2 S
5880·3	10	1, 2
5859·6	9	0, 1 S
5609·5	10	1, 1
5586·4	10	0, 0 S
5423·8	7	3, 2
5389·4	8	2, 1
5359·4	9	1, 0 S
5228·5	5	4, 2
5192·3	4	3, 1
5158·1	2	2, 0 S
5051·0	3	5, 2
5013·0	3	4, 1
4976·4	2	3, 0 S

MoO ?

Continuous emission and faint bands in the region 6500–6100 A. have been observed when molybdenum oxide MoO_3 is introduced into a flame or arc.

Reference. G. Piccardi, *Accad. Lincei Atti.*, **17,** 654. (1933).

N_2

There are a number of band systems attributed to the neutral nitrogen molecule. In emission the first and second positive systems are the most readily developed, the second positive being the more sensitive in a discharge through air (such as a leak in a discharge tube), the presence of oxygen appearing to favour this system relatively to the first positive bands. Other systems which appear in emission are the fourth positive bands, the Vegard-Kaplan bands, a part of the Lyman-Birge-Hopfield system, van der Ziel's system, and some weak systems reported by Kaplan. Lyman, Birge and Hopfield have observed several systems in absorption in the vacuum ultra-violet, but none of these extend into the quartz region.

The best established electronic levels for nitrogen in order of energy from the ground state are $X^1\Sigma$, $A^3\Sigma$, $a^1\Pi$, $B^3\Pi$, $C^3\Pi$, $D^3\Sigma$. There are several other excited levels corresponding to Birge-Hopfield absorption systems, van der Ziel's system (two Σ levels) and Kaplan's systems.

First Positive System

Occurrence. In the positive column of discharge tubes containing nitrogen or air. The bands appear very readily.

Appearance. Degraded to the violet. Under small dispersion the appearance is of waves of regularly spaced triple-headed bands strongest in the orange, the red and the yellow-green. Under large dispersion the rotational structure is seen to be complex, and there are several heads to each band. See Plate 3.

Transition. $B\,^3\Pi \rightarrow A\,^3\Sigma$.

References. A. Fowler and R. J. Strutt, *P.R.S.*, **85,** 377. (1911)†.
A. H. Poetker, *P.R.*, **30,** 812. (1928)†.
H. Birkenbeil, *Z.P.*, **88,** 1. (1934).

N_2 (*contd.*)

In the following table the first heads of the bands as listed by Birkenbeil (which include Poetker's measurements in the infra-red) are given with the addition of those listed by Fowler and Strutt as occurring strongly in the nitrogen afterglow. The intensities I_d and I_a are for an ordinary discharge and for the nitrogen afterglow respectively in which the intensity distributions are very different. The values of I_d in the infra-red are thermocouple measurements by Poetker, and in the visible the intensities are our own estimates from Fowler and Strutt's published photographs.

λ	I_d	I_a	v′, v″	λ	I_d	I_a	v′, v″	
10420	10		0, 0	6544·8	10		7, 4	
9860	1		2, 2	6468·5	10		8, 5	
9599	3		3, 3	6394·7	9		9, 6	
9362	3		4, 4	6322·9	7	2	10, 7	
9133	2		5, 5	6252·8	3	5	11, 8	
8911·6	10		1, 0	6185·2	3	1	12, 9	4, 0
8722·3	8		2, 1	6127·4	3		5, 1	
8541·8	6		3, 2	6069·7	7		6, 2	
8369·2	2		4, 3	6013·6	7		7, 3	
8204·8	3		5, 4	5959·0	8		8, 4	
8047·4	2		6, 5	5906·0	8		9, 5	
7896·4	2		7, 6	5854·4	8	4	10, 6	
7753·2	6		2, 0	5804·3	7	10	11, 7	
7626·2	7		3, 1	5755·2	7	8	12, 8	
7503·9	7		4, 2	5632·7	1		5, 0	
7386·6	5		5, 3	5592·9	1		6, 1	
7273·3	3		6, 4	5553·7	1		7, 2	
7164·8	2		7, 5	5515·6	2		8, 3	
7059·0	2		8, 6	5478·5	2		9, 4	
6967·8	1		9, 7	5442·3	3	1	10, 5	
6875·0	2		3, 0	5407·1	3	5	11, 6	
6788·6	6		4, 1	5372·8	3	5	12, 7	
6704·8	8		5, 2	5053·6		2	11, 5	
6623·6	9		6, 3	5030·8		2	12, 6	

Second Positive System

Occurrence. In the positive column of discharge tubes containing nitrogen or air and in arcs at low pressure. The bands appear very readily and are of frequent occurrence as an impurity.

Appearance. Degraded to shorter wave-lengths. Close triple-headed bands forming fairly obvious sequences. See Plate 3.

Transition. $C\,^3\Pi \rightarrow B\,^3\Pi$.

References. R. Mecke and P. Lindau, *Phys. Zeit.*, **25**, 277. (1924).
D. Coster, H. Brons and A. van der Ziel, *Z.P.*, **84**, 304. (1933).

The following measurements are by R. C. Pankhurst and A. G. Gaydon from spectrograms taken on a Hilger E.1 and on a 20-ft. concave grating spectrograph :—

N_2 (*contd.*)

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4976·4	0	4, 11	4059·4	8	0, 3	3371·3	10	0, 0
4916·8	0	1, 7	3998·4	9	1, 4	3339	2*	1, 1
4814·7	1	2, 8	3943·0	8	2, 5	3309	2*	2, 2
4723·5	1	3, 9	3894·6	7	3, 6	3285·3	3	3, 3
4667·3	0	0, 5	3857·9	5	4, 7	3268·1	4	4, 4
4649·4	1	4, 10	3804·9	10	0, 2	3159·3	9	1, 0
4574·3	2	1, 6	3755·4	10	1, 3	3136·0	8	2, 1
4490·2	3	2, 7	3710·5	8	2, 4	3116·7	6	3, 2
4416·7	3	3, 8	3671·9	6	3, 5	3104·0	3	4, 3
4355·0	3	4, 9	3641·7	3	4, 6	2976·8	6	2, 0
4343·6	4	0, 4	3576·9	10	0, 1	2962·0	6	3, 1
4269·7	5	1, 5	3536·7	8	1, 2	2953·2	6	4, 2
4200·5	6	2, 6	3500·5	4	2, 3	2819·8	1	3, 0
4141·8	5	3, 7	3469	0	3, 4	2814·3	1	4, 1
4094·8	4	4, 8	3446	0	4, 5			

* The intensities of the (1, 1) and (2, 2) bands relative to the (0, 0) band seem to vary considerably in different sources. In some sources using pure nitrogen they are often weak, but on spectrograms of a discharge through air they may be quite strong.

Fourth Positive System

Occurrence. In mildly condensed discharge through nitrogen.

Appearance. Degraded to shorter wave-lengths. A single progression of bands each with five close heads.

Transition. $D\,^3\Sigma \rightarrow B\,^3\Pi$.

Reference. A. Fowler and R. J. Strutt, *P.R.S.*, **85**, 377. (1911)†.

Bands as listed by Fowler and Strutt :—

λ	I	v′, v″	λ	I	v′, v″
2903·9	1	0, 6	2448·0	10	0, 2
2902·0			2447·0		
2900·3			2445·6		
2898·1			2444·0		
2896·6			2442·8		
2777·9	2	0, 5	2351·4	6	0, 1
2776·5			2350·3		
2775·1			2349·0		
2772·8			2347·5		
2771·4			2346·4		
2660·5	5	0, 4	2260·8	2	0, 0
2659·3			2259·6		
2657·9			2258·4		
2655·8			2257·1		
2654·5			2256·0		
2550·7	8	0, 3			
2549·7					
2548·4					
2546·6					
2545·3					

N_2 (*contd.*)

VEGARD-KAPLAN BANDS

Occurrence. This is a relatively weak "intercombination" system, and is only observed strongly under rather special conditions of excitation. The system was first reported by Vegard in the spectrum of the luminescence of solid nitrogen. Kaplan produced the bands in a special discharge tube consisting of a short length of 1 mm. capillary and a 500 c.c. bulb ; an uncondensed discharge was used and the bands also appeared in the afterglow. Bernard has succeeded in observing another part of the system by exciting a mixture of nitrogen and argon with an electron beam. Some of the bands occur in the aurora.

Appearance. Degraded to the red. Kaplan and Bernard report the bands as single headed, but in the luminescence of solid nitrogen Vegard observed a weak and a strong head to each.

Transition. $A\,^3\Sigma \rightarrow X\,^1\Sigma$, ground state.

References. J. Kaplan, *P.R.*, **45**, 675. (1934)†, and numerous short letters and abstracts, mostly in *Phys. Rev.*
R. Bernard, *C.R. Acad. Sci. Paris*, **200**, 2074. (1935).

The following are the bands as observed by Kaplan ; intensities are our own estimates from his small published photograph :—

λ	I	v′, v″	λ	I	v′, v″
3424·6	4	1, 10	2603·8	10	0, 5
3197·5	5	1, 9	2560·1	2	2, 6
2997·0	2	1, 8	2509·8	6	1, 5
2935·7	9	0, 7	2461·6	9	0, 4
2760·6	9	0, 6	2424·2	0	2, 5
2710·1	0	2, 7	2377·5	7	1, 4
2655·5	1	1, 6	2332·8	4	0, 3

The bands observed by Vegard from solid nitrogen have their stronger heads 125 cm.$^{-1}$ (around 10 A.) to the red of the heads listed by Kaplan.

The following are the strong bands as observed by Bernard :—

λ	I	v′, v″	λ	I	v′, v″
5060·1	4	0, 14	4072·5	3	2, 13
4837·1	8	2, 15	3979·1	3	1, 12
4649·7	4	4, 16	3940·3	4	7, 16
4616·5	3	7, 18	3889·2	4	0, 11
4535·5	5	3, 15	3854·7	3	3, 13
4319·8	2	1, 13	3603·0	4	0, 10
4171·2	4	3, 14	3502·7	3	2, 11

LYMAN-BIRGE-HOPFIELD SYSTEM

Occurrence. The main part of the system which lies in the vacuum ultra-violet is readily observed in absorption and emission. With a high current-density discharge the system can be extended to about 2500 A.

Appearance. Degraded to the red. Apparently single-headed bands.

Transition. $a\,^1\Pi \rightarrow X\,^1\Sigma$, ground state.

References. R. T. Birge and J. J. Hopfield, *Astrophys. J.*, **68**, 257. (1928)†.
E. T. S. Appleyard, *P.R.*, **41**, 254. (1932).
J. Kaplan and L. Levanas, *P.R.*, **46**, 331. (1934).

N_2 (*contd.*)

The following measurements are by Appleyard, except the (3, 12) band which is converted to λ_{air} from Birge and Hopfield's vacuum measurements :—

λ	v′, v″	λ	v′, v″
2162·3	7, 16	2059·0	6, 14
2143·9	6, 15	*2041·2	5, 13
*2125·9	5, 14	2023·5	4, 12
2089·7	3, 12	2006·0	3, 11

* Relatively strong.

VAN DER ZIEL'S SYSTEM

Occurrence. High current-density discharge through nitrogen.

Appearance. Degraded to shorter wave-lengths. Single-headed bands.

Transition. Van der Ziel has made a rotational analysis of the bands, but it is not certain whether the transition is $^1\Sigma \rightarrow {}^1\Sigma$ or $^3\Sigma \rightarrow {}^3\Sigma$.

Reference. A. van der Ziel, *Physica*, **1**, 513. (1934).

λ	v′, v″	λ	v′, v″	λ	v′, v″
2781·6	0, 8	2556·0	1, 7	2181·5	0, 1
2743·0	1, 9	*2496·9	0, 5	2165·1	1, 2
2681·2	0, 7	2469·7	1, 6	*2112·1	0, 0
2647·0	1, 8	*2411·7	0, 4	2033·6	1, 0
2586·5	0, 6	2235·9	1, 3		

* A rotational analysis has been made for these bands, which are therefore presumably relatively strong ; no intensities are available.

KAPLAN'S SYSTEMS

Kaplan has of recent years made an extensive study of the nitrogen spectrum ; most of his investigations have been made using a discharge tube similar to that used for the production of the Vegard-Kaplan bands ; the results of these investigations have appeared in numerous short letters and abstracts, mostly in *Physical Review*.

References. J. Kaplan, *P.R.*, **46**, 631. (1934) ; *P.R.*, **47**, 259. (1935).

The following three systems of bands are all degraded to shorter wave-lengths and are claimed to have a common $^1\Sigma$ final level with the van der Ziel system, although this is doubted by van der Ziel (*Physica*, **4**, 373 (1937)).

System 1		System 2		System 3	
λ	v′, v″	λ	v′, v″	λ	v′, v″
*2381	0, 3	*2740	0, 3	2472	0, 7
2366	1, 4	2720	1, 4	2392	0, 6
*2301	0, 2	*2635 ?	0, 2	2316	0, 5
2288	1, 3	2620	1, 3	2242	0, 4
*2225	0, 1	*2536	0, 1		
*2153	0, 0	2522	1, 2		
		2510	2, 3		
		2432	1, 1		
		2421	2, 2		

* Relatively strong.

Kaplan has also observed the following groups or progressions of bands :—

λλ2428, 2360, 2297, 2236.

λλ2459, 2367, 2280, 2198.

λλ2272, 2204, 2139,

λλ2477, 2391, 2309,

N_2 (*contd.*)

and the following unidentified bands: λλ2682, 2670, 2647, 2640, 2603, 2597, 2570, 2530, 2527, 2512, 2501, 2495, 2489, 2462, 2384, 2372, 2356, 2336, 2262, 2177.

N_2^+

Occurrence. In discharge tubes at very low pressure or at moderate pressure in presence of excess of helium, in hollow cathode, and in negative glow.

Appearance. Strong bands are degraded to shorter wave-lengths, but a few weak bands are degraded to the red. Single-headed. See Plate 3.

Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

References. T. R. Merton and J. G. Pilley, *Phil. Mag.*, **50**, 195. (1925).
D. Coster and H. H. Brons, *Z.P.*, **70**, 492. (1931).

The following table is from Merton and Pilley. These bands are degraded to shorter wave-lengths. Intensities I_{he} and I_n are for Tesla coil discharge through helium containing a trace of nitrogen and for ordinary discharge through nitrogen at low pressure.

λ	I_{he}	I_n	v′, v″
5864·7	4	0	0, 4
5653·1	4	1	2, 6
5564·1	1	0	3, 7
5485·5	5	0	4, 8
5228·3	7	2	0, 3
5148·8	4	3	1, 4
5076·6	7	1	2, 5
5012·7	3	1	3, 6
4957·9	5	1	4, 7
4709·2	4	2	0, 2
4651·8	4	1	1, 3
4599·7	6	2	2, 4
4554·1	4	0	3, 5
4515·9	6	0	4, 6
4490·3	2	1	5, 7
4278·1	8	6	0, 1
4236·5	7	5	1, 2
4199·1	4	2	2, 3
4166·8	3	0	3, 4
4140·5	2	–	4, 5
3914·4	6	6	0, 0
3884·3	3	1	1, 1
3857·9	2	2	2, 2
3835·4	1	1	3, 3
3818·1	1	0	4, 4
3582·1	4	3	1, 0
3563·9	4	0	2, 1
3548·9	3		3, 2
3538·3	2		4, 3
3532·6	1	0	5, 4
3308·0	2	1	2, 0
3298·7	3	1	3, 1
3293·4	3	0	4, 2

Coster and Brons report the two bands degraded to the red :—

3612·4 (10, 9) 3381·3 (10, 8)

NBr

Occurrence. In afterglow of nitrogen containing bromine.

Appearance. Three sequences of bands degraded to the violet. The system is not unlike the first positive bands of nitrogen, but on a smaller scale.

Reference. A. Elliott, *P.R.S.*, **169**, 469. (1939)†.

The following are the strong bands ; the intensities are our estimates from the published photograph :—

NBr (*contd.*)

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
6404·8	5	1, 0	6075·9	4	3, 1	5905·0	10	9, 7
6370·1	5	2, 1	6047·9	7	4, 2	5876·2	5	10, 8
6335·4	7	3, 2	6019·5	9	5, 3	5741·9	6	7, 4
6300·2	7	4, 3	5990·7	10	6, 4	5718·6	8	8, 5
6265·9	8	5, 6	5962·4	10	7, 5	5695·1	8	9, 6
6231·1	8	6, 5	5933·8	10	8, 6	5671·5	4	10, 7
6196·0	6	7, 6						

In addition, there are a few unassigned bands, but these mostly appear to be weak.

NH

Of the four systems reported the triplet system at 3360 A. is most readily excited.

References. A. Fowler and C. C. L. Gregory, *Phil. Trans. Roy. Soc.*, **A218**, 251. (1919)†.
G. W. Funke, *Z.P.*, **96**, 787. (1935).

3360 A. System, $^3\Pi \rightarrow {}^3\Sigma$, ground state.

Bands scarcely degraded in either direction so that Q branches form a strong central maximum of intensity, while the R and P branches spread out symmetrically. Branches consist of narrow triplets whose spacing decreases with increasing rotation. Under low dispersion the Q-maxima of the 0, 0 and 1, 1 bands are often mistaken for an atomic doublet.

The system occurs under a wide range of conditions ; in flames such as the ammonia-oxygen flame and moist cyanogen flame ; in discharge tubes containing nitrogen and hydrogen ; in low pressure arcs ; controlled electron discharges ; active nitrogen and chemiluminescence where nitrogen and hydrogen are both present. See Plate 4.

v′, v″	λ	
0, 0	3360	Broad Q maxima.
1, 1	3370	

References. R. W. B. Pearse, *P.R.S.*, **143**, 112. (1933)†.
G. Nakamura and T. Shidei, *Jap. Jour. of Phys.*, **10**, 5. (1934).

3240 A. System, $^1\Pi \rightarrow {}^1\Delta$

Bands degraded to the red. Branches consist of very narrow doublets whose spacing increases with rotation ; the R branch is much weaker than the P and Q. The system occurs in discharge tubes ; in chemiluminescence and in active nitrogen where hydrogen and nitrogen are present together. See Plate 4.

	Heads	
v′, v″	R	Q
0, 1	3609·6	3627·2
0, 0	3240·1	3253·4
1, 0	3035·2	3042·6

NH (*contd.*)

References. R. W. Lunt, R. W. B. Pearse and E. C. W. Smith, *P.R.S.*, **151**, 602. (1935)†.

4502 A. SYSTEM, $^1\Pi \rightarrow {}^1\Sigma$

Band degraded to the red. Single P, Q and R branches. Observed in controlled electron discharges in ammonia and in hollow cathode discharge with rapidly streaming ammonia.

v′, v″	R Head	Q Head
0, 0	4502·0	4523·2

Reference. R. W. Lunt, R. W. B. Pearse and E. C. W. Smith, *P.R.S.*, **155**, 173. (1936)†.

2530 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Pi$

Band degraded to the violet observed by Hori in high tension discharge through a mixture of hydrogen and nitrogen in presence of sodium or lithium. Occurs also in hollow cathode with streaming ammonia.

v′, v″	P Head	Q Head
0, 0	2557·3	2530·2

NH_2? Ammonia α band

Occurrence. In flame of ammonia burning in oxygen, and weakly in a discharge through streaming ammonia.

Appearance. This band structure extends throughout the visible, being strongest in the yellow and green ; it is responsible for the yellow-green colour of the ammonia flame. The band is of the " many-line " type, showing a very large number of fine lines, without heads or obvious regularity. The structure seems too complex for a diatomic molecule of the type of NH, and yet the experimental evidence of its production suggests that it is a decomposition product of ammonia rather than NH_3 itself which is the emitter. It seems likely to be due to NH_2.

Reference. W. B. Rimmer, *P.R.S.*, **103**, 696. (1923)†.

Rimmer has given measurements of some 300 lines of this band, with intensities on a scale of 6. The following are the strongest lines (intensities listed as 4, 5 or 6) :—

λ	I	λ	I	λ	I
6332·82	6	5624·40	5	4975·05	4
6325·18	5	5621·03	5	4746·26	4
6300·81	5	5597·39	4	4743·56	4
5977·29	5	5563·62	5	4722·5	6
5972·16	4	5560·56	5	4704·00	4
5708·46	6	5547·42	4	4702·18	4
5707·00	6	5527·46	4	4680·04	5
5705·36	6	5525·04	6	4541·94	5
5697·17	4	5429·19	5	4540·37	4
5673·16	4	5384·64	5	4510·98	4
5641·17	5	5166·23	6	4465·34	4

NH_3, Ammonia

Schuster's Emission Band

Occurrence. In uncondensed discharge through streaming ammonia.
Appearance. A strong continuum in the yellow-green with maxima at 5635 A. and 5670 A.
Reference. W. B. Rimmer, *P.R.S.*, **103**, 696. (1923)†.

Ultra-Violet Absorption

Occurrence. Absorption by gaseous ammonia.
Appearance. Rather diffuse double (or triple) headed bands, shaded to the red, occur in the region below 2300 A., the bands getting stronger in the shorter wave-length region. In the vacuum ultra-violet the bands are strong and well defined.
References. M. Ferrieres, *C.R. Acad. Sci. Paris*, **178**, 202. (1924).
A. B. F. Duncan, *P.R.*, **47**, 822. (1935).

The following are the maxima of the principal bands as compiled from the above references :—

λ	I	λ	I
2245	1	2086·4	5
2239		2084·1	
2211	2	2048·4	6
2206		2045·7	
2167·3	4	2010·9	7
2163·7			
2126·5	4		
2123·9			

Vibration-Rotation Spectrum

Occurrence. In absorption by gaseous ammonia.
Appearance. Bands composed of complex line-structure. The strongest band probably shows a maximum of intensity (the Q branch) at 7919 A. and perhaps a head degraded to the red at 7874 A.
Reference. R. M. Badger and R. Mecke, *Zeit. phys. Chem.*, **5**, 333. (1929).

λ		
6450	$5\nu_1$	weak
7919	$4\nu_1$	strong
8800	$3\nu_1 + \nu_2$	weak

NO

Three band systems of nitric oxide have been observed in emission, these being known as the β, γ, and δ systems, and a fourth system has been observed in absorption in the far ultra-violet.

β System

Occurrence. In discharge tubes containing oxygen and nitrogen and in the nitrogen afterglow, and especially strongly when excess of oxygen is introduced into active nitrogen.
Appearance. Degraded to red. Double-headed. See Plate 3.
Transition. $^2\Pi \rightarrow {}^2\Pi$, ground state.
References. R. C. Johnson and H. G. Jenkins, *Phil. Mag.*, **2**, 621. (1926).
F. A. Jenkins, H. A. Barton and R. S. Mulliken, *P.R.*, **30**, 150. (1927)†.

O (*contd.*)

The wave-lengths of the R heads of both sub-bands are given. The strong bands are from Jenkins, Barton and Mulliken's measurements, others by Johnson and Jenkins.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5270·1	0	3, 18	3583·5	10	0, 10	2809·4	4	1, 6
5252·7			3572·4			2802·6		
4912·1	2	3, 17	3456·9	2	1, 10	2786·0	3	
4892·1			3446·0			2779·5		
4810·0	1	2, 16	3408·5	1	3, 11	2754·3	9	0, 5
4791·4			3398·9			2747·6		
4590·8	5	3, 16	3386·4	10	0, 9	2731·7	1	2, 6
4574·0			3376·4			2725·4		
4496·2	3	2, 15	3364·3	0		2678·7	7	1, 5
4479·8			3355·2			2672·2		
4401·5	2	1, 14	3340·3	3	2, 10	2626·6	6	0, 4
4385·7			3330·7			2620·5		
4309·7	3	0, 13	3298·6	0	4, 11	2608·3	6	2, 5
4293·7			3289·7			2602·1		
4303·1	3	3 15	3206·9	10	0, 8	2557·9	5	1, 4
4288·2			3198·0			2551·8		
4215·2	4	2, 14	3168·3	3	2, 9	2542·2	2	3, 5
4200·7			3159·8			—		
4127·9	4	1, 13	3131·1	2	4, 10	2528·7	0	
4113·6			3125·0			2523·2		
4041·8	6	0, 12	3043·0	10	0, 7	2493·4	7	2, 4
4027·8			3034·9			2487·8		
3962·7	2	2, 13	3010·7	1	2, 8	2433·0	7	3, 4
3949·8			3002·8			2427·8		
3880·7	5	1, 12	2950·8	3	1, 7	2386·4	1	2, 3
3868·3			2943·2			2381·5		
3800·9	10	0, 11	2923·1	4	3, 8	2331·4	3	3, 3.
3788·5			2915·9			2326·6		
3658·5	4	1, 11	2892·6	10	0, 6			
3647·2			2885·2					

γ SYSTEM (NITROGEN THIRD POSITIVE)

Occurrence. In discharge tubes containing nitrogen and oxygen, in active nitrogen, and in flames containing nitric oxide.

Appearance. Degraded to shorter wave-lengths. Double double-headed bands. The strongest bands form a single v″ progression. See Plate 3.

Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.

References. W. H. Bair, *Astrophys. J.*, **52**, 301. (1920).
M. Guillery, *Z.P.*, **42**, 121. (1927).
R. Schmid, *Z.P.*, **64**, 84. (1930).
R. J. Strutt, *P.R.S.*, **93**, 254. (1917)†.

Most of the measurements given below are by Bair, his original values being raised by from 0·5 to 0·2 A. to bring them into agreement with those bands which

NO (*contd.*)

have been measured more accurately. Only the P_1 heads are given by Bair. Where available the P_2 heads are also given. The Q_1 and Q_2 heads are about 1 A. to the shorter wave-length side of the P heads. The intensities are our own estimates.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3458·5	0	1, 10	2722·2	9	0, 4 P_1	2244·3	2	1, 1 P_1
3375·5		0, 8	2713·2		P_2	2239		P_2
3303·0		3, 12	2680·0	5	1, 5 P_1	2221·3	2	2, 2 P_1
3278·5	0	1, 9	2671		P_2	2216		P_2
3201·1		2, 10	2638·9	2	2, 6	2198·5		3, 3
3170·7	0	0, 7	2610·8		3, 7	2181·9		4, 4
3120·6		3, 11	2595·7	10	0, 3 P_1	2156	3	1, 0
3112·4	0	1, 8	2587·5		P_2	2134		2, 1
3044·3		2, 9	2558·6	5	1, 4 P_1	2115		3, 2
3008·8	4	0, 6 P_1	2551		P_2	2099		4, 3
2997·6		P_2	2525·3	1	2, 5	2078		5, 4
2984·4	0	3, 10	2497·4		3, 6	2060		2, 0
2949·6	0	1, 7	2478·7	10	0, 2 P_1	2035		3, 1
2898·4	0	2, 8	2471·1		P_2	2021		4, 2
2859·5	6	0, 5 P_1	2447	2	1, 3	2003		5, 3
2849·8		P_2	2416	1	2, 4	System extends to 1667 A.		
2849·4		3, 9	2385·0		3, 5			
2810·4	5	1, 6	2370·2	9	0, 1 P_1			
2763·3	2	2, 7	2363·3		P_2			
2735·9		3, 8	2330·2	0	1, 2			
			2316·0	1	2, 3			
			2288·9	1	3, 4			
			2269·4	5	0, 0 P_1			
			2263·0		P_2			

δ SYSTEM

Occurrence. In active nitrogen. Also in absorption.

Appearance. Degraded to shorter wave-lengths. Double-headed bands, each head being a close double.

Transition. $^2\Sigma \longrightarrow {}^2\Pi$, ground state.

References. H. P. Knauss, *P.R.*, **32**, 417. (1928).
R. Schmid, *Z.P.*, **64**, 279. (1930)†.

In the following table wave-lengths given to 0·1 A. are by Schmid, the $^2\Pi_{\frac{1}{2}}$ and $^2\Pi_{1\frac{1}{2}}$ sub-bands being denoted by i and ii. The intensities and wave-lengths of the last three bands are by Knauss.

λ	I	v′, v″	λ	I	v′, v″
2317·7	2	0, 5 P ii	2141·3	4	0, 3 P ii
2316·5		Q ii	2140·3		Q ii
2311·4		P i	2135·8		P i
2310·3		Q i	2134·8		Q i
2226·8	3	0, 4 P ii	2062	3	0, 2
2225·6		Q ii	1987	2	0, 1
2220·8		P i	1913	1	0, 0
2219·6		Q ii			

NO^+

Occurrence. In discharge tube containing flowing NO or NO_2.

References. M. Duffieux and L. Grillet, *C.R. Acad. Sci. Paris,* **202,** 937. (1936).
C. Jausseran, L. Grillet, and M. Duffieux, *C.R. Acad. Sci. Paris,* **205, 39.** (1937).

λ5999

Symmetrical band with P and R branches. Q branch weak or absent. Under very high dispersion the lines of the P and R branches are observed to be triple. Origin at 5998·9 A.

NO_2

The spectrum of NO_2 has been observed almost exclusively in absorption. It is extremely complicated and very extensive. For descriptive purposes it may be divided into two regions here referred to as the Visible and Ultra-violet Systems respectively.

The Visible System

Occurrence. Readily obtained in absorption from NO_2 vapour. To obtain the spectrum in a pure state the temperature should be chosen so that N_2O_4 is decomposed but NO_2 is still stable (about 120° C.).

Appearance. With small amounts of gas a number of bands are obtained in the violet and ultra-violet regions, showing sharp rotational structure at the violet end but becoming more and more diffuse toward the ultra-violet and finally merging into a continuum. As the quantity of gas is increased the absorption spreads step by step to the red and sharp bands may be followed down to about 9000 A. It is possible that more than one electronic system is involved.

References. V. Henri, " The Structure of Molecules," p. 131. Edited by P. Debye. (1932).
L. Harris and R. W. B. Pearse, unpublished data.

Individual bands vary greatly in appearance. The following are some of the more outstanding edges and maxima :—

λ	I	λ	I
5095 M	3	4545 R	4
5048 M	3	4480 M	10
5027 M	3	4448 R	8
4945 M	3	4390 R	8
4880 R	3	4350 M	6
4795 M	3	4304 R	5
4740 R	5	4270 R	5
4630 R	6	4133 M	5
4605 M	3	4102 M	4
4580 M	4	4081 R	3

These are followed by many bands growing wider and more diffuse to about 3200 A.

The Ultra-violet System

Occurrence. Obtained readily in absorption under the same conditions as the system in the visible.

Appearance. With a small quantity of gas two bands have sharp heads degraded to the red and show a very open rotational structure resembling a single Q branch. Other bands have been observed as far as 2000 A. but are all diffuse. With a greater quantity of gas other sharp bands to the red are observed.
References. As for Visible System.

The strongest bands are as follows :—

λ		I	
2491·4	R	6	sharp
2459·3	R	5	sharp
2446·7	R	5	diffuse
2430	R	2	diffuse
2419	R	10	diffuse
2390	R	8	diffuse
2372	R	8	very wide
2363	M	4	diffuse
2351	M	9	diffuse

Further diffuse bands to 2000 A.

NS

There are two systems similar to the β and γ systems of NO. They have thus been designated as β and γ by Fowler and Bakker.

β System

Occurrence. In discharge through nitrogen mixed with sulphur vapour.
Appearance. Pairs of bands degraded to red.
Transition. Probably $^2\Pi \rightarrow {}^2\Pi$, ground state.
Reference. A. Fowler and C. J. Bakker, *P.R.S.*, **136**, 28. (1932)†.

The two sub-bands are indicated by i and ii.

λ	I	v′, v″	λ	I	v′, v″
2697·4	5	1, 3 i	2540·1	2	2, 2 ii
2683·3	4	1, 3 ii	2518·5	8	0, 0 i
2680·0	4	0, 2 i	2506·7	8	0, 0 ii
2667·0	3	0, 2 ii	2477·8	3	2, 1 i
2614·6	4	1, 2 i	2465·6	3	2, 1 ii
2601·2	3	1, 2 ii	2460·7	7	1, 0 i
2597·1	6	0, 1 i	2448·7	6	1, 0 ii
2584·8	5	0, 1 ii	2406·0	4	2, 0 i
2553·1	3	2, 2 i	2394·4	4	2, 0 ii

γ System

Occurrence. In discharge through nitrogen mixed with sulphur vapour.
Appearance. Degraded to shorter wave-lengths. A single progression of double double-headed bands.
Transition. Probably $^2\Sigma \rightarrow {}^2\Pi$, ground state.
Reference. A. Fowler and C. J. Bakker, *P.R.S.*, **136**, 28. (1932)†.

The two sub-bands are indicated by i and ii. Only the P heads are listed. The Q heads lie about 1·2 A. to the violet of these.

λ	I	v′, v″	λ	I	v′, v″
2587·0	1	0, 4 ii	2383·6	10	0, 1 i
2525·7	3	0, 3 i	2371·1	10	0, 1 ii
2511·5	3	0, 3 ii	2317·2	10	0, 0 i
2453·0	5	0, 2 i	2305·2	8	0, 0 ii
2439·7	4	0, 2 ii			

Na_2

Band systems attributed to Na_2 have been observed in the red, in the blue-green, and several in the ultra-violet.

Red System

Occurrence. In absorption, in fluorescence, in magnetic rotation, and in emission in a discharge tube.
Appearance. Degraded to the red. Single-headed bands.
Transition. $^1\Sigma \rightarrow {}^1\Sigma$, ground state.
Reference. W. R. Fredrickson and W. W. Watson, *P.R.*, **30**, 429. (1927).

The following are the strongest bands (listed as intensity 5) in absorption :—

λ	v′, v″	λ	v′, v″
6751·2	1, 2	6513·2	3, 0
6679·7	1, 1	6465·8	4, 0
6630·1	2, 1	6418·4	5, 0
6561·5	2, 0	6374·2	6, 0

Blue-green System

Occurrence. Similar to red system.
Appearance. Degraded to the red.
Transition. $^1\Pi \rightarrow {}^1\Sigma$, ground state.
References. W. R. Fredrickson and W. W. Watson, *P.R.*, **30**, 429. (1927).
F. W. Loomis and R. W. Wood, *P.R.*, **32**, 223. (1928).

The intensities as listed in the above references do not agree very well, but the following include the strong bands as observed in absorption :—

λ	v′, v″	λ	v′ v″
5040·4	0, 3	4894·5	1, 0
5001·4	0, 2	4865·5	2, 0
4962·8	0, 1	4837·2	3, 0
4932·6	1, 1	4819·5	5, 1
4924·2	0, 0	4809·8	4, 0

Ultra-violet Systems

Walter and Barratt have observed numerous bands in the ultra-violet λλ3526–2470 in absorption by sodium vapour, and these have been analysed by Wiezel and Kulp into several systems. All the bands are degraded to the red, and originate in the $^1\Sigma$ ground state.

References. J. M. Walter and S. Barratt, *P.R.S.*, **119**, 257. (1928).
W. Weizel and M. Kulp, *Ann. Physik*, **4**, 971. (1930).

Na_2 (*contd.*)

The following are the strongest bands as observed by Walter and Barratt :—

λ	I	λ	I	λ	I	λ	I
3486	4	3414	8	3357	6	3268	4
3468	8	3400	8	3339	3	3263	4
3450	10	3383	8	3326	3	3257	4
3432	10	3370	6	3280	4	3252	4

NaCd

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd). Heads λλ4000 and 3974.

NaCs

References. See LiCs.

Absorption bands observed by Walter and Barratt, and arranged into three systems by Weizel and Kulp. Degraded to the red. Strongest heads (intensity 10) : λλ5631, 5602, 5571, 5542, 5492, 5463, 5444, 5425, 4136, 4098.

NaH

References. T. Hori, *Z.P.*, **62**, 352. (1930).
T. Hori, *Z.P.*, **71**, 478. (1931).
E. Olsson, *Z.P.*, **93**, 206. (1934).

4500 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$, ground state

A many-lined system with weak R heads degraded to the red. The system is readily obtained in absorption from a mixture of hydrogen and sodium vapour and in emission from a sodium arc in hydrogen or a discharge through a mixture of hydrogen and sodium vapour.

Origins of the Strongest Bands

v′, v″	λ	I	v′, v″	λ	I
5, 1	4376·5	4	7, 0	4049·5	7
6, 1	4309·7	5	8, 0	3991·5	9
7, 1	4244·3	5	9, 0	3934·9	10
4, 0	4231·4	0	10, 0	3879·9	10
8, 1	4180·6	4	11, 0	3826·5	9
5, 0	4169·7	2	12, 0	3774·8	9
6, 0	4109·0	5	13, 0	3724·9	9

NaHg

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd). Heads λλ6499, 6454, 4649, 4425 and 4406.

NaK

Four systems, in the near infra-red, the yellow, the green and the violet respectively, have been attributed to NaK.

Occurrence. All four systems have been observed in absorption by a mixture of sodium and potassium vapours. The yellow and green systems have also been observed in magnetic rotation, and the latter has been obtained in fluorescence.

Appearance. All the systems are degraded to longer wave-lengths.

NaK *(contd.)*

INFRA-RED SYSTEM

Transition. $B\,^1\Sigma \leftarrow A\,^1\Sigma$, ground state.
Reference. F. W. Loomis and M. J. Arvin, *P.R.*, **46**, 286. (1934).
Bands 9100–7200 A. Strongest head : λ8338 (3, 3).

YELLOW SYSTEM

Transition. $C\,^1\Pi \leftarrow A\,^1\Sigma$, ground state.
References. F. W. Loomis and M. J. Arvin, *P.R.*, **46**, 286. (1934).
S. Barratt, *P.R.S.*, **105**, 221. (1923–4)†.

The following are the bands observed by Barratt in absorption with their probable analysis :—

λ	v′, v″	λ	v′, v″	λ	v′, v″	λ	v′, v″
5955·0	1, 2	5824·6	5, 1	5746·1	7, 0	5680·9	11, 0
5931·8	0, 1	5803·7	6, 1 ?	5728·6	8, 0	5667·4	12, 0
5867·0	?	5783·5	7, 1 ?	5712·1	9, 0	5654·1	13, 0
5846·0	6, 2	5764·3	6, 0	5696·0	10, 0	5645·2	?

GREEN SYSTEM

Transition. $C'\,^1\Pi \leftarrow A\,^1\Sigma$, ground state.
Reference. F. W. Loomis and M. J. Arvin, *P.R.*, **46**, 286. (1934).
Strong bands :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5230·4	3	0, 8	5114·9	3	1, 5	5032·5	3	2, 3
5198·9	5	0, 7	5083·6	3	1, 4	5011·8	3	3, 3
5167·5	5	0, 6	5063·4	5	2, 4	5001·8	3	2, 2
5145·6	3	1, 6	5052·2	5	1, 3	4992·3	3	4, 3
5136·3	3	0, 5						

VIOLET SYSTEM

References. J. M. Walter and S. Barratt, *P.R.S.*, **119**, 257. (1928).
Y. Uchida, *Japan. Jour. Physics*, **5**, 145. (1929).
W. Weizel and M. Kulp, *Ann. Physik*, **4**, 971. (1930).

The following are the strongest bands recorded by Walter and Barratt : λλ3958, 3923, 3905, 3886 and 3874. The analyses proposed by Uchida and by Weizel and Kulp are different.

NaRb

Bands, degraded to the red, have been observed in absorption by a mixture of sodium and rubidium vapours.
References. See LiCs.
Strongest bands : λλ5432, 5397, 5368, 5339, 5331.

NdO

Occurrence. Neodymium salts in oxy-hydrogen flame.
Reference. G. Piccardi, *Rend. Accad. Linc.*, **21**, 584. (1935).

NdO (*contd.*)

The following are the strongest heads :—

λ	I	λ	I	λ	I
6629·6	8	6585·2	15	5999	8
6624·6	8	6370·9	8	5996	8
6620·2	7	6368·6	8	5990·7	10
6606·7	10	6353·5	9	5975	10
6602·4	10	6349·9	10	5971·1	8
6598·3	10	6002	8	4620·0	8

NiBr or $NiBr_2$

Occurrence. In high-frequency discharge through nickel bromide vapour.
Reference. P. Mesnage, *Thesis for doctorate, Paris.* (1938).

The bands are degraded to longer wave-lengths. There is a strong system with 0, 0 band at λ4590·2 and other fragmentary analyses are proposed by Mesnage.

Strongest bands :—

λ	I	λ	I	λ	I
4744·0	4	4598·3	7	4257·7	4
4669·0	5	4590·2	10	4231·4	4
4664·6	4	4554·8	4	4037·4	5
4659·6	5	4541·6	4	3988·0	4
4637·2	4	4456·3	5	3930·1	5
4604·5	6	4354·3	4		

NiCl or $NiCl_2$

Occurrence. High-frequency discharge through nickel chloride vapour.
Reference. P. Mesnage, *C.R. Acad. Sci. Paris,* **200,** 2072 (1935); and *Thesis for doctorate, Paris.* (1938).

The following are the strongest bands, which are degraded to the red. Some of the bands have been arranged into fragmentary analyses by Mesnage.

λ	I	λ	I	λ	I
5352·2	4	4305·0	6	4095·3	7
5013·2	6	4215·9	5	4094·3	5
4709·3	4	4146·2	4	4081·3	4
4563·0	4	4100·2	4	4061·3	5
4309·1	4				

NiH

References. A. G. Gaydon and R. W. B. Pearse, *P.R.S.*, 148, 312. (1935)†.
A. Heimer, *Z.P.*, **105,** 56. (1936)†.

6442 A. System. $^2\Delta_{2\frac{1}{2}} \rightarrow {}^2\Delta_{2\frac{1}{2}}$

Band showing widely-spaced R and P branches with narrow doublets. A Q branch is observed near the origin but quickly decreases in intensity with increasing rotation. Occurs in flames fed with nickel carbonyl, in high-tension arcs in hydrogen flame, and in discharges where hydrogen and nickel vapour are present together.

	Heads		
v′, v″	R	Q	I
0, 0	6425·1	6443·3	4

NiH (*contd.*)

6257 A. SYSTEM, $^2\Delta_{2\frac{1}{2}} \rightarrow {}^2\Delta_{2\frac{1}{2}}$

Bands similar in appearance to the above system and occurring under similar conditions.

	Heads		
v′, v″	R	Q	I
0, 0	6246·0	6260·1	10
1, 0	5712·5	5724·8	7
2, 0	5290·0	5300·5	2
3, 0	4952·1	4962·0	1

4207 A. SYSTEM, $^2\Delta_{2\frac{1}{2}} \rightarrow {}^2\Delta_{2\frac{1}{2}}$

Bands similar in appearance and occurrence to those of the other two systems.

	Heads	
v′, v″	R	Q
0, 1	4570·5	4579·5
0, 0	4200·6	4208·3

There is also much weak unsystematised band-structure in the orange and red; there are weak heads (deg. R) at λλ6391·8, 6171·5 and 5834·3.

NiO

Occurrence. In flame containing nickel carbonyl, and in nickel arc burning in air.
Appearance. Degraded to red. Heads ill-defined under high dispersion.
Transition. Unknown. Attributed to NiO on experimental grounds only.
The following measurements by Gaydon. Intensities are for flame.

λ	I	λ	I	λ	I
6721	0	5454·9	2	4849·2	2
6704	2	5407·7	8	4790·1	0
6604·5	0	5323·4	2	4751·0	8
6385·8	5	5174·5	10	4744·5	0
6342·2	8	5098·3	3	4721·4	0
6152·1	5	5026	2	4714·6	2
6133·3	8	5006·6	5	4665·7	5
6036	0	4979·6	0	4662·2	0
5935·5	2	4938·8	0	4633	0
5914·1	5	4889·5	5	4606·5	2
5529·5	8	4876·7	5	4545·6	2
5488·6	0	4860·1	2	4994·3	0

O_2

The neutral oxygen molecule does not readily show an emission spectrum. A part of the main absorption system observed by Schumann has been observed in emission by Runge, and Hopfield has reported an emission spectrum in the region below 2218 A. There are several weak absorption systems, including the atmospheric absorption bands and Herzberg's system. The absorption spectrum of liquid oxygen is also described briefly.

SCHUMANN-RUNGE SYSTEM

Occurrence. The main part of this system lies in the vacuum ultra-violet below 1900 A.; using heated oxygen and greater thicknesses of gas the absorption bands

O_2 (*contd.*)

have been extended into the quartz region by Füchtbauer and Holm. Runge has observed a part of the system in emission in a high tension arc in oxygen.

Appearance. Degraded to longer wave-lengths.

Transition. B $^3\Sigma \rightarrow$ X $^3\Sigma$, ground state.

References. Absorption, S. W. Leifson, *Astrophys J.*, **63**, 73. (1926)†.

Absorption by heated gas, C. Füchtbauer and E. Holm, *Phys. Zeits.*, **26**, 345. (1925).

Emission, W. Lochte-Holtgreven and G. H. Dieke, *Ann. Physik.*, **3**, 937. (1929).

The following measurements of the emission bands observed by Runge are by Lochte-Holtgreven and Dieke ; the values are for the origins of the bands, but as these are so strongly degraded, the origins are less than 0·5 A. from the heads, which are of course to the shorter wave-length side. The intensities are on a scale of 6 based on the intensities of individual lines.

λ_0	I	v′, v″	λ_0	I	v′, v″	λ_0	I	v′, v″
4372·6	5	2, 21	3987·3	4	2, 19	3516·6	5	0, 15
4292·4	5	1, 20	3912·8	5	1, 18	3500·0	2	2, 16
4214·7	5	0, 19	3841·1	6	0, 17	3370·1	5	0, 14
4173·2	6?	2, 20	3742·2	5	1, 17	3356·8	3	2, 15
4095·9	6	1, 19	3673·2	5	0, 16	3232·9	4	0, 13
4021·1	5	0, 18	3583·0	3	1, 16	3104·3	4	0, 12

HOPFIELD'S EMISSION SYSTEM

Occurrence. Condensed discharge through oxygen and helium.

Appearance. Degraded to shorter wave-lengths. One progression.

Reference. J. J. Hopfield, *P.R.*, **36**, 789. (1930).

The following are the bands observed : λλ2217·5, 2170·0, 2123·1, 2076·6, 2030·8. The bands may be a v′ progression with the 2031 band as the (0, 0).

ATMOSPHERIC ABSORPTION

Occurrence. In atmospheric absorption (especially solar spectrum). The bands have also been observed in the laboratory by absorption through pure oxygen.

Appearance. The bands are degraded to longer wave-lengths, but the heads are in some cases weak.

Transition. A $^1\Sigma \leftarrow$ X $^3\Sigma$, ground state.

References. G. H. Dieke and H. D. Babcock, *Proc. Nat. Acad. Sci., U.S.A.*, **13**, 670. (1927).

W. Ossenbruggen, *Z.P.*, **49**, 167. (1928).

R. Mecke and W. Baumann, *Z.P.*, **73**, 139. (1932).

The following measurements are compiled from the above. Intensities are our own estimates based on the references.

λ Head	λ Origin (approx.)	I	v′, v″
7685	7708	2?	1, 1
7593·7	7620	10	0, 0
6867·2	6883	8	1, 0
6276·6	6287	3	2, 0
5788·1	5796	1	3, 0
5380	—	0	4, 0

O_2 (*contd.*)

HERZBERG ABSORPTION BANDS

Occurrence. Absorption. Herzberg used 25 metres of oxygen at 1 atm. Finkelnberg and Steiner used compressed oxygen and extended the system to longer wave-lengths.
Appearance. Headless bands, but with some branches degraded to the red. Under small dispersion the bands appear to have triple maxima, the centre one being strongest.
References. G. Herzberg, *Naturwiss.*, **20**, 577. (1932).
W. Finkelnberg and W. Steiner, *Z.P.*, **79**, 69. (1932)†.

Herzberg assumes the bands are a $v'' = 0$ progression and gives the following wave-lengths of the origins λλ2595, 2554·0, 2519·1, 2488·5, 2463·0, 2442·8, 2429·0.

Finkelnberg and Steiner give the following groups. No intensities are available, but the bands to shorter wave-lengths appear at lower pressures (*i.e.*, are the strongest).

λ	λ	λ	λ
—	2510	2625	2775
2440	2518	2632	2784
—	2525	2642	2796
2458	2543	2672	2832–2859
2465	2553	2678	
2473	2561	2690	
2481	2583	2721	
2489	2591	2730	
2497	2600	2740	

LIQUID ABSORPTION

Occurrence. Absorption by liquid oxygen.
Appearance. Degraded to longer wave-lengths.
Reference. J. C. McLennan, H. D. Smith, and J. O. Wilhelm, *Trans. Roy. Soc. Canada*, iii, **24**, 65. (1930)†.

The following measurements represent the limits of the bands; most of the bands have fairly sharp heads and the longer wave-length edge is the head. Intensities are our estimates from the published photographs. The bands have been analysed into several systems.

λ limits	I	λ limits	I	λ
10420–10220	?	4802–4710	3	2863
9300–9100	?	4628–4605	0	2800
8300–8200	?	4481–4456	2	2763
7665–7590	3	4208–4180	1	2735
6916–6875	0	3930–3920	0	2686
6368–6160	10	3825–3785	3	2639
5826–5640	9	3628–3585	3	continuous
5364–5290	4	3455–3423	?	absorption
4982–4916	1	3305–3274	?	below 2609

The bands in the visible region have also been observed in absorption by solid oxygen, with slight changes of wave-length and intensity.

O_2 (*contd.*)

FAR ULTRA-VIOLET ABSORPTION

The absorption by atmospheric oxygen sets the ultra-violet limit to spectroscopic work with quartz spectrographs in air. At this limit bands, degraded to the red, are observed. The following measurements are by Liefson (*Astrophys. J.*, **63**, 73. (1926)): λλ1924·8, 1903·1, 1883·0, 1864·0, 1846·9, 1831·1, 1816·8, 1804·3, 1793·4, 1783·9, 1775·9, 1769·2, 1763·8, 1759·6, 1755·7.

These bands belong to the Schumann-Runge system, and can be extended, by heating the gas, as far as 2400 A., but in this region show only complex rotational structure without definite heads.

O_2^+

There are two easily obtained systems of bands which are attributed to the ionised oxygen molecule, the First Negative oxygen bands from the red to the green, and the Second Negative in the ultra-violet.

FIRST NEGATIVE SYSTEM

Occurrence. In discharge tubes containing oxygen, especially in the negative glow or at low pressure.

Appearance. Degraded to the violet. Under small dispersion the appearance is of five strong bands similar in position and type to the Angstrom bands of CO.

Transition. $^4\Sigma \rightarrow {}^4\Pi$.

References. R. Frerichs, *Z.P.*, **35**, 683. (1926).
L. Bozoky and R. Schmid, *P.R.*, **48**, 465. (1935).
T. E. Nevin, *Phil. Trans. Roy. Soc. A.*, **237**, 471. (1938)†.

The following wave-lengths are from the above references: no intensities are given, but the strong bands are indicated :—

λ	v′, v″	λ	v′, v″	λ	v′, v″
7891	0, 4	5973·4	1, 1	5566·6	3, 2
7348	0, 3	5925·6	2, 2	5540·7	4, 3
6856·3	0, 2 strong	5883·4	3, 3	5295·7	2, 0 strong
6418·7	0, 1 strong	5847·3	4, 4	5274·7	3, 1
6351·0	1, 2	5631·9	1, 0 strong	5005·6	3, 0
6026·4	0, 0 strong	5597·5	2, 1		

SECOND NEGATIVE SYSTEM

Occurrence. In discharge tubes containing oxygen, especially in the negative glow, at low pressures, or in the presence of excess of helium. Also in high-frequency discharge.

Appearance. Degraded to the red. An extensive system of double-headed bands, separation about 200 cm.$^{-1}$.

Transition. $^2\Pi \rightarrow {}^2\Pi$, lowest known state of ionised oxygen.

References. R. C. Johnson, *P.R.S.*, **105**, 683. (1923–24)†.
V. M. Ellsworth and J. J. Hopfield, *P.R.*, **29**, 79. (1927)†.
R. S. Mulliken and D. S. Stevens, *P.R.*, **44**, 720. (1933).

O_2^+ (*contd.*)

In the following table the bands with intensities are from Johnson's measurements; bands without recorded intensities are from the other references quoted above; they are relatively weak bands. The R_2 and R_1 heads are denoted by ii and i following the vibrational quantum numbers.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
6102·9		1, 14 ii	3210·8	8	2, 5 i	2458·6	1	8, 2 ii
5678·3		1, 13 i	3141·0	5	1, 4 ii	2446·9	1	8, 2 i
5498·4		0, 12 ii	3123·1	5	1, 4 i	2433·5	3	6, 1 ii
5443·0		0, 12 i	3062·8	8	2, 4 ii	2421·8	2	6, 1 i
5086·3		0, 11 ii	3043·6	8	2, 4 i	2392·6	3	7, 1 ii
5035·1		0, 11 i	2987·5	8	3, 4 ii	2381·0	3	7, 1 i
4877·6		1, 11 ii	2970·0	7	3, 4 i	2354·3	1	8, 1 ii
4820·3		1, 11 i	2919·8	8	4, 4 ii	2343·3	1	8, 1 i
4720·7		0, 10 ii	2907·1	5	2, 3 ii	2328·7		6, 0 ii
4678·5		0, 10 i	2901·9	7	4, 4 i	2317·9		6, 0 i
4399·4		0, 9 ii	2890·3	7	2, 3 i	2307·2		9, 1 i
4363·1		0, 9 i	2839·7	9	3, 3 ii	2291·8		7, 0 ii
4115·8	8	0, 8 ii	2823·7	8	3, 3 i	2285·8		10, 0 ii
4082·4	8	0, 8 i	2776·7	7	4, 3 ii	2281·3		7, 0 i
3859·5	8	0, 7 ii	2761·9	7	4, 3 i	2275·3		10, 1 i
3830·5	8	0, 7 i	2720·0	7	5, 3 ii	2252·8		11, 1 ii
3733·9	8	1, 7 ii	2705·3	7	5, 3 i	2246·9		8, 0 i
3706·6	8	1, 7 i	2688·5	2	3, 2 i	2243·5		11, 1 i
3629·8	8	0, 6 ii	2666·5	4	6, 3 ii	2224·3		9, 0 ii
3620·1	2	2, 7 ii	2652·3	4	6, 3 i	2213·8		9, 0 i
3603·7	7	0, 6 i	2646·7	6	4, 2 ii	2183·9		10, 0 i
3594·5	2	2, 7 i	2632·7	6	4, 2 i	2164·0		11, 0 ii
3517·7	8	1, 6 ii	2594·3	8	5, 2 ii	2155·3		11, 0 i
3494·2	7	1, 6 i	2581·0	8	5, 2 i	2138·6		12, 0 ii
3421·2	8	0, 5 ii	2545·5	7	6, 2 ii	2128·4		12, 0 i
3416·2	2	2, 3 ii	2532·8	6	6, 2 i	2112·2		13, 0 ii
3397·8	8	0, 5 i	2512·9	3	4, 1 i	2103·7		13, 0 i
3393·1	4	2, 6 i	2500·6	6	7, 2 ii	2090·3		14, 0 ii
3322·6	6	1, 5 ii	2488·3	6	7, 2 i	2080·8		14, 0 i
3300·3	6	1, 5 i	2478·0	4	5, 1 ii	2068·3		15, 0 ii
3231·2	8	2, 5 ii	2465·8	2	5, 1 i	2059·7		15, 0 i

O_3

Ultra-violet System

Occurrence. These bands occur strongly in absorption by ozone; this absorption is of course responsible for the ultra-violet limit of solar radiation reaching the earth. Bands, probably identical with these absorption bands, have been observed by Johnson in a mildly-condensed discharge through oxygen.

Appearance. The usual appearance of ozone absorption is a fairly sharp cut-off in the ultra-violet, between 3000 A. and 3600 A., according to the thickness of ozone, with a few narrow bands showing up clearly in the neighbourhood of this cut-off. The bands are headless, but in some cases appear slightly degraded to the red. The

O_3 (*contd.*)

bands are clearest in the region 3200–3400 A.; they extend to below 2500 A., but are only faintly visible above the continuous absorption in most regions.

References. A. Fowler and R. J. Strutt, *P.R.S.*, **93**, 577. (1917)†.
O. R. Wulf and E. H. Melvin, *P.R.*, **38**, 330. (1931)†.
A. Jakowlewa and V. Kondratjew, *Phys. Zeit. Sowjetunion*, **1**, 471. (1932).
R. C. Johnson, *P.R.S.*, **105**, 683. (1924)†. (Emission.)

The following measurements are by Fowler and Strutt; these agree well with those of Jakowlewa and Kondratjew, whose measures are however lower by about 1 A. The bands have been partly analysed by Wulf and Melvin and by Jakowlewa and Kondratjew.

λ	I	λ	I	λ	I	λ	I
3432·2	1	3311·5	5d	3227·2	10	3171·6	4
3421·4	1	3304·1	3	3221·5	10	3162·6	2d
3402·6	1	3284·0	2	3206·8	2	3156·1	8
3377·7	1	3279·8	8d	3201·0	8d	3137·4	10d
3374·1	3	3272·0	3	3194·8	6	3114·3	8d
3365·2	1	3255·5	5	3188·8	1	3105·0	5
3346·0	1	3249·7	8	3181·5	1	3096·5	4
3338·5	4	3243·0	1d	3177·0	8d	3089·5	8d
3331·2	1	3232·8	1				

d = diffuse.

The following are the emission bands as observed by Johnson. They are rather badly masked by the strong oxygen first negative bands.

λ	I	λ	I	λ	I	λ	I
4464·7	1	3568·9	2	3337·8	6	3278·1	2
4333·3	2	3565·2	1	3331·5	4	3106·1	5
4316·5	5	3465·3	0	3313·1	5	3097·5	4
4276·9	2	3378·3	1	3284·6	2	3090·4	8

Visible Absorption Bands

Wulf has observed absorption bands of ozone in the orange and in the infra-red, using long columns of the gas. There are two strong diffuse bands at about 5730 and 6020 A. The cut-off in the infra-red varies from around 9000 A. for short paths of ozone, up to the limit of the visible, and finally the absorption merges with the orange bands for very long paths.

Reference. O. R. Wulf, *Proc. Nat. Acad. Sci., U.S.A*, **16**, 507. (1930)†.

OH

References. W. W. Watson, *Astrophys. J.*, **60**, 145. (1924)†.
L. Grebe and O. Holtz, *Ann. Physik.*, **39**, 1243. (1912).
D. Jack, *P.R.S.*, **115**, 373. (1927)†.
118, 647. (1928).
120, 222. (1928).
T. Tanaka and Z. Koana, *Proc. Phys. Math. Soc. Japan*, **15**, 272. (1933).

OH (*contd.*)

3064 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Pi$, GROUND STATE

Bands degraded to the red with four heads, two R and two Q. The most clearly defined is the higher frequency R head, the others being much overlapped. The system occurs in emission in almost all sources where water vapour is present, such as flames, arcs, and discharge tubes. May be obtained in absorption when conditions are such that sufficient concentration of free OH radicals is maintained. See Plate 4.

v′, v″	R_2	R_1	Q_2	Q_1	I
2, 0	2608·5	2613·4	2613·4	2622·1	3
3, 1	2677·3	2683·1	2681·8	2691·1	2
1, 0	2811·3	2816·0	2819·1	2829·0	6
2, 1	2875·3	2880·6	2882·3	2892·7	3
3, 2	2945·2	2951·2	2951·2	2962·4	1
0, 0	3063·6	3067·2	3078	3089	10
1, 1	3121·7	3126·4	—	—	—
2, 2	3184·8	3190·2	3195·9	3208·7	—
0, 1	3428·1	3432·1	3458·5	3472·1	2

OH^+

References. F. W. Loomis and W. H. Brandt, *P.R.*, **49**, 55. (1936)†.
W. H. Rodebush and M. H. Wahl., *J. Chem. Phys.*, **1**, 696. (1933)†.

3565 A. SYSTEM, $^3\Pi \rightarrow {}^3\Sigma$

Complex bands degraded to the red, each showing nine strong branches, three P, three Q, and three R.

Discovered by Rodebush and Wahl in an electrodeless discharge through water vapour. Obtained in a similar manner by Loomis and Brandt in a special D-shaped discharge tube.

v′, v″	Heads R
0, 1	3893
1, 1	3695
0, 0	3565
1, 0	3332

P_2

Only one band system has so far been definitely attributed to diatomic phosphorus.

Occurrence. In emission, especially in discharge tubes with hydrogen as a carrier of the discharge, in fluorescence and in absorption.

Appearance. Degraded to the red. This is a very extensive system of single-headed bands extending throughout the ultra-violet; the large number of bands of about equal intensity is a characteristic feature of the spectrum.

Transition. $^1\Sigma \rightarrow {}^1\Sigma$, ground state.

References. A. Jakowlewa, *Z.P.*, **69**, 548. (1931).
G. Herzberg, *Ann. Physik.*, **15**, 677. (1932).
M. F. Ashley, *P.R.*, **44**, 919. (1933)†.

Emission. The following measurements are from Herzberg :—

P_2 (*contd.*)

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3222·9	4	11, 30	2845·7	5	3, 18	2565·6	4	7, 15
3201·9	4	10, 29	2830	–*	5, 19	2562·1	5	4, 13
3184·1	4	9, 28	2774·5	4*	5, 18	2520·8	5	7, 14
3166·2	5	8, 27	2757·1	6*	4, 17	2516·6	6	4, 12
3141·1	4	10, 28	2707·4	4*	7, 18	2513·6	5	1, 10
3123·3	5	9, 27	2690·5	5	6, 17	2509·6	4	9, 15
3105·4	5	8, 26	2689·3	4*	3, 15	2472·5	4	4, 11
3082·0	5	10, 27	2645·2	5	9, 18	2468·6	4	1, 9
3069·5	5	6, 24	2642·1	4	6, 16	2461·0	6	6, 12
3064·2	4	9, 26	2628·1	5	8, 17	2456·9	6	3, 10
3046·4	4	8, 25	2625·5	5*	5, 15	2450·6	5	8, 13
3028·7	4	7, 24	2586·6	5	11, 18	2413·7	4	3, 9
2953·6	7	6, 22	2582·0	5	8, 16	2403·3	5	5, 10
2898·0	4*	6, 21	2578·0	4	5, 14	2393·3	4	7, 11

* These bands appear prominently on the reproduction by Ashley.

Only bands listed by Herzberg as intensity 4 or greater are given above; this only represents a small fraction of the whole system.

Absorption. Strongest bands listed by Jakowlewa :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2261·6	4	1, 4	2128·6	4	2, 1	2074·9	5	3, 0
2186·4	4	1, 2	2122·6	5	4, 5	2069·0	5	5, 1
2164·3	5	2, 3	2108·1	6	3, 1	2055·0	5	4, 0
2150·0	5	1, 1	2094·3	4	2, 0	2050·0	4	6, 1
2143·0	5	3, 4	2088·3	4	4, 1	2036·0	5	5, 0

PH

Reference. R. W. B. Pearse, *P.R.S.*, **129**, 328. (1930)†.

3400 A. System, $^3\Pi_i \rightarrow {}^3\Sigma$

Complex band obtained in emission from a discharge tube containing phosphorus vapour and hydrogen.

v′, v″	Heads λ (I)				
0, 0	3390·1 (5)	3394·9 (7)	3409·2 (4)	3419·6 (10)	3426·8 (5)

PN

Occurrence. In heavy-current discharge tubes containing phosphorus and nitrogen.

Appearance. Degraded to the red. Close double-headed bands (separation about 0·6 A.). Well-marked sequences.

Transition. $^1\Pi \rightarrow {}^1\Sigma$.

Reference. J. Curry, L. Herzberg and G. Herzberg, *Z.P.*, **86**, 348. (1933)†.

The following are the strong bands. The intensities have been reduced to a scale of 10. The R heads only are given here.

PN (*contd.*)

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2742·9	3	3, 5	2620·1	8	1, 2	2466·2	7	2, 1
2727·5	4	2, 4	2605·0	9	0, 1	2451·1	8	1, 0
2712·1	4	1, 3	2533·0	3	1, 1	2418·7	3	4, 2
2696·9	3	0, 2	2518·2	10	0, 0	2403·3	3	3, 1
2635·2	4	2, 3	2481·4	3	3, 2	2388·2	2	2, 0

PO

Two band systems in the ultra-violet have been attributed to PO. They correspond to the β and γ system of nitric oxide. Bands have also been observed in the visible by Geuter using flame and discharge tube sources ; the emitting molecule is uncertain but may be PO.

β System λλ3241–3587

Occurrence. In arcs and discharge tubes containing phosphorus and oxygen, and in flames containing phosphorus oxychloride.

Appearance. There is a strong sequence of bands commencing at around 3240 A. and getting weaker to longer wave-lengths ; this sequence has no marked head and the bands of which it is formed show heads degraded in both directions. There are two similar weaker sequences further to the red.

Transition. $^2\Pi \rightarrow {}^2\Pi$, ground state.

References. P. Geuter, *Zeit. f. wissen. Photographie,* **5**, 33. (1907).
A. Petrikaln, *Z.P.*, **51**, 395. (1928)†.
J. Curry, L. Herzberg and G. Herzberg, *Z.P.*, **86**, 364. (1933).

No detailed analysis of this system has been published ; the following molecular constants are recorded by Curry, Herzberg and Herzberg, $\nu_0 = 30584$ cm^{-1} (λ=3270), $\omega'_0 = 1151$, $\omega''_0 = 1228$. Petrikaln publishes a photograph of the system and wave-lengths but no intensities or analysis ; he obtained the bands in a discharge tube. The following measurements of the strong heads are by Geuter for emission in an arc ; the wave-lengths published by Geuter and by Petrikaln do not correspond very well. The letters R and V indicate that the head is degraded to longer or shorter wave-lengths.

λ	I	λ	I	λ	I
3424·7 V?	3	3346·3 R	3	3270·5 V	6
3414·2 V	3	3328·4 R	4	3268·9 R	5
3405·8 V	3	3311·9 R	5	3266·7 V?	3
3397·9 V	3	3296·4 R	5	3255·3 V	6
3388·0 V	3	3285·8 R	3	3253·4 R	5
3379·8 V	3	3280·7 V?	4	3246·3 V	6

γ System, λλ2750–2280

Occurrence. Phosphorus compounds in carbon arc, in discharge tubes containing phosphorus and oxygen, and in flames.

Appearance. Degraded to shorter wave-lengths. The bands are double double-headed and the sequences are fairly well marked.

Transition. A $^2\Sigma \rightarrow$ X $^2\Pi$, ground state.

References. A. Petrikaln, *Z.P.*, **51**, 295. (1928)†.
P. N. Ghosh and G. N. Ball, *Z.P.*, **71**, 362. (1931)†.

PO (*contd.*)

The following measurements of the strong bands are by Ghosh and Ball. The intensities are our own estimates from the published photographs by Petrikaln and by Ghosh and Ball. All the bands are double-headed, the separation between the P and Q heads being about 1·3 A.; only the P heads are given below.

λ	I	v′, v″	λ	I	v′, v″	λ	λ	v′, v″
2721·5	1	0, 3 P_1	2595·7	2	2, 4 P_2	2387·9	7	2, 1 P_1
2706·8	3	1, 4 P_1	2555·0	10	0, 1 P_1	2383·5	8	1, 0 P_2
2705·1	1	0, 3 P_2	2543·9	7	1, 2 P_1	2379·9	2	3, 2 P_1
2692·4	4	2, 5 P_1	2540·4	10	0, 1 P_2	2375·2	7	2, 1 P_2
2690·8	4	1, 4 P_2	2529·4	7	1, 2 P_2	2367·3	2	3, 2 P_2
2676·7	4	2, 5 P_2	2518·7	5	2, 3 P_2	2320·6	3	2, 0 P_1
2662·9	3	3, 6 P_2	2477·9	10	0, 0 P_1	2313·7	4	3, 1 P_1
2636·3	7	0, 2 P_1	2468·3	6	1, 1 P_1	2306·9	4	4, 2 P_1
2623·4	7	1, 3 P_1	2464·2	10	0, 0 P_2	2301·7	4	3, 1 P_2
2620·5	8	0, 2 P_2	2459·0	2	2, 2 P_1	2300·4	3	5, 3 P_1
2610·7	2	2, 4 P_1	2454·6	6	1, 1 P_2	2294·9	3	4, 2 P_2
2608·0	7	1, 3 P_2	2396·3	8	1, 0 P_1	2288·2	2	5, 3 P_2

Pb_2

Occurrence. Absorption by lead vapour; also in thermal emission.
Appearance. Degraded to the red. Long v″ = 0 progression.
Reference. E. N. Shawhan, *P.R.*, **48,** 343. (1935)†.

Bands in region 5200–4600 A. Strongest heads: λλ4890·2 (6, 0), 4855·0 (7, 0), 4821·0 (8, 0).

PbBr

Occurrence. In absorption.
Appearance. Degraded to red.
Reference. F. Morgan, *P.R.*, **49,** 47. (1936).
Strongest bands :—

λ	v′, v″	λ	v′, v″
5092·1	0, 6	4818·5	2, 2
5040·4	0, 5	4597·1	6, 0
5002·0	1, 5	4566·9	7, 0
4902·5	1, 3	4537·5	8, 0
4866·4	2, 3	4509·5	9, 0

PbCl

Occurrence. High-frequency discharge through $PbCl_2$ vapour, and in absorption. Also fluorescent emission.
Appearance. Degraded to red.
References. G. D. Rochester, *P.R.S.*, **153,** 407. (1935)†.
F. Morgan, *P.R.*, **49,** 47. (1936).

Strongest bands (intensities listed by Rochester as 9 or 10) :—

PbCl (*contd.*)

λ	v′, v″	λ	v′, v″	λ	v′, v″
5358·3	4, 14	5062·0	0, 7	*4596·0	1, 1
5342·1	3, 13	4988·2	0, 6	*4548·9	2, 1
5263·1	3, 12	4916·5	0, 5	*4399·0	4, 0
5169·5	2, 10	*4846·0	0, 4	*4356·5	5, 0
5153·4	1, 9	*4660·3	1, 2		

* Observed in absorption but not in emission, probably because of self-absorption.

PbF

Occurrence. High-frequency discharge through lead fluoride vapour, and in absorption.

Appearance. Degraded to red. Marked sequences.

References. G. D. Rochester, *P.R.S.*, **153**, 407. (1935)†.
F. Morgan, *P.R.*, **49**, 47. (1936).

Heads of strong sequences :—

λ	Sequence
4647·7	0, 2
4542·5	0, 1
4441·2	0, 0
4364·8	1, 0

PbH

Reference. W. W. Watson, *P.R.*, **54**, 1068. (1938).

5560 A. System, $^2\Sigma \rightarrow {}^2\Sigma$

Band spectrum of the many-lined type, obtained with 1000 v. lead arc in hydrogen at pressures of four to five atmospheres. Each band possesses four branches degraded to the red. Origins :—

v′, v″	λ	v′, v″	λ
3, 0	5178	2, 1	5764
2, 0	5296	1, 1	5904
1, 0	5423	0, 1	6065
0, 0	5563	0, 2	6647

PbO

Five band systems known as A, B, C, D, and F, are attributed to lead oxide.

Occurrence. All five systems have been observed in absorption in a carbon arc furnace. Systems A, B, and D are emitted by an arc (between carbon or copper electrodes) containing lead or lead salts and in flame sources. System C also probably occurs in emission.

References. S. Bloomenthal, *P.R.*, **35**, 34. (1930).
A. Christy and S. Bloomenthal, *P.R.*, **35**, 46. (1930).
H. G. Howell, *P.R.S.*, **153**, 683. (1935–6).
L. Withrow and G. M. Rassweiler, *Ind. Eng. Chem.*, **23**, 769. (1931)†.

System A, λλ6720–4748.

Appearance. Degraded to red.

Transition. Probably $^1\Sigma \rightarrow {}^1\Sigma$, ground state.

Strong bands. Intensities (for emission) on scale of 6.

PbO (*contd.*)

λ	I	v′, v″
6433·6	3	3, 8
6427·7	3	0, 6
6342·0	3	2, 7
6250·7	5	1, 6
6160·5	4	0, 5
5910·7	6	0, 4
5677·8	6	0, 3
5617·6	3	2, 4
5459·4	6	0, 2
5331·1	3	1, 2
5138·2	3	1, 1
5068·8	1	0, 0

System B, λλ5770–4146

Appearance. Degraded to red. A strong progression on each side of the weak (0, 0) band.

Transition. To ground state.

Strong bands. Intensities (for emission) on scale of 6.

λ	I	v′, v″
5353·8	3	0, 5
5162·3	6	0, 4
4983·8	6	0, 3
4816·9	6	0, 2
4658·0	5	0, 1
4553·7	6	1, 1
4509·2	1	0, 0
4410·4	5	1, 0
4317·1	4	2, 0
4229·0	4	3, 0

System C, λλ4156–3607

Degraded to red. Intensities for absorption. Strong bands :—

λ	I	v′, v″
4156·2	3	0, 1
4037·6	3	0, 0
3987·7	4	2, 1
3955·0	7	1, 0
3877·8	8	2, 0
3804·9	6	3, 0

System D. λλ3594–3209

Appearance. Degraded to red.

Transition. Probably $^1\Sigma \rightarrow {}^1\Sigma$, ground state.

Bands as observed by Bloomenthal in emission. Many more bands have been observed in absorption.

λ	I	v′, v″
3594·2	1	1, 4
3485·7	6	0, 2
3442·8	1	2, 3
3401·9	5	0, 1
3341·8	2	1, 1
3320·7	1	0, 0
3264·4	2	1, 0
3209·2	2	2, 0

System F, λλ2925–2753

(0,1) 2865·5 (1,1) 2836·6 (0, 0) 2808·6 (1, 0) 2780·0 A.

It is to be noted that for all systems the wave-lengths given by Howell and by Bloomenthal differ by sometimes as much as an angstrom, although both express their results to 0·01 A.

PbS

Reference. G. D. Rochester and H. G. Howell, *P.R.S.*, **148**, 157. (1935)†.

Numerous bands, all degraded to longer wave-lengths, have been observed between 3100 and 8000 A. in absorption. The bands have been arranged into five systems. The following are the strongest heads (listed as intensity 10) :—
λλ5999·1, 5630·2, 5549·1, 5499·8, 5228·5, 5159·0, 5047·5, 4982·7, 4919·9, 4858·5, 4798·9, 4563·5, 4421·3, 4368·1, 4316·5, 4266·4, 3530·6, 3478·7, 3443·4, 3428·3, 3393·9.

PbSe

Three systems of bands, all degraded to the red, have been observed in absorption.

Reference. J. W. Walker, J. W. Straley and A. W. Smith, *P.R.*, **53**, 140. (1938).

The following are the strongest heads :—

System A., λλ5674·3, 5372·6, 5325·1, 5278·7, 5203·2, 5202·6, 5158·6.
System B., λλ4921·2, 4855·9, 4813·1, 4791·3, 4749·0, 4708·4, 4570·9.
System C., λλ4165·9, 4134·9, 4104·9.

PbTe

Two systems, both degraded to the red, have been observed in absorption.

Reference. See PbSe.

The following are the strongest heads :—

System A., λλ5777·3, 5731·7, 5686·8.
System B., λλ5054·4, 5018·0, 4965·3, 4930·8, 4896·4, 4863·3.

PrO

Occurrence. In flame or arc fed with præsodymium salts.

Reference. W. W. Watson, *P.R.*, **53**, 639. (1938).

Heads of strongest sequences (degraded to the red) :—

λ	I
5763·4	9
5691·0	10
5596·6	8
5352·0	

Bands, including the above, have also been observed by G. Piccardi (*Accad. Lincei. Atti.*, **23**, 358 (1936)) and by C. J. Rodden and O. S. Plantinga (*P.R.*, **45**, 280. (1934)).

Rb_2

Several band systems have been observed and attributed to the rubidium molecule. For most of these wave-lengths and intensities are not available.

References. J. C. McLennan and D. S. Ainslie, *P.R.S.*, **103**, 304. (1923)†.
J. M. Walter and S. Barratt, *P.R.S.*, **119**, 257. (1928).
E. Matuyama, *Nature*, **133**, 567. (1934).

λ8800 System

Bands observed in absorption by Matuyama.

Rb_2 (*contd.*)

RED SYSTEM

Observed in absorption and fluorescence. Matuyama gives $\nu_e = 14666$ cm.$^{-1}$. McLennan and Ainslie record the following wave-lengths: 7099·7, 7065·3, 7030·1, 6997·8, 6967·1, 6937·9, 6909·6, 6884·1, 6858·6, 6832·2, 6807·3, 6792·3, 6781·3, 6763·0, 6744·8, 6725·5, and 6706·3. The bands are degraded to longer wave-lengths.

ORANGE SYSTEM

Walter and Barratt report bands at λλ6054, 6033 and 5992, degraded to the red, in absorption.

λ4800 SYSTEM.

Observed in absorption. Matuyama gives $\nu_e = 20930$ cm.$^{-1}$.
Walter and Barratt record a strong head at λ4746 and weaker heads at 5081 and 4703.

λ4350 SYSTEM

Observed in absorption. Matuyama gives $\nu_e = 22968$ cm.$^{-1}$.

RbCd

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd.). Heads λλ4487 and 4423. Also bands 4400–4200 A.

RbCs

A diffuse band at λ5640 has been observed by J. M. Walter and S. Barratt (*P.R.S.*, **119**, 257. (1928)) in absorption.

RbH

5300 A. SYSTEM

Occurrence. In discharge tubes containing a mixture of hydrogen and rubidium vapour. By analogy with the other alkali-metal hydrides it may be expected to occur in the rubidium arc in hydrogen, and in absorption from a mixture of hydrogen and rubidium vapour.

Appearance. A very extensive many-line system with weak R heads degraded to the red.

Transition. $^1\Sigma \rightarrow {}^1\Sigma$, ground state.

Reference. A. G. Gaydon and R. W. B. Pearse, *P.R.S.*, **173**, 28. (1939)†.

Origins of the strongest bands.

v′, v″	λ	I	v′, v″	λ	I
1, 2	5871·4	8	6, 1	5193·5	8
2, 2	5783·4	10	4, 0	5098·1	5
3, 2	5696·2	10	5, 0	5028·1	5
4, 2	5610·1	8	6, 0	4959·3	5
2, 1	5502·9	7	7, 0	4892·1	7
3, 1	5423·9	8	8, 0	4826·3	5
4, 1	5345·8	9	9, 0	4762·2	5
5, 1	5268·9	9	10, 0	4699·9	4

RbHg

Diffuse bands, degraded to the violet, observed in absorption by Barratt (see CsCd.). Heads λλ6364, 6335 and 4879. Also mention of bands λλ4400–4200.

RbZn

Mention of absorption bands λλ4400–4200. See CsCd.

S_2

Occurrence. In sources containing sulphur vapour, especially vacuum-tube discharge, arc, and flame of CS_2 burning in oxygen.

Appearance. Degraded to red. Very extensive system of roughly equally-spaced bands. See Plate 5.

Transition. $^3\Sigma \rightarrow {}^3\Sigma$, ground state.

References. A. Christy and S. M. Naudé, *P.R.*, **37**, 903. (1931).
W. E. Curtis and S. Tolansky, *Durham Phil. Soc.*, p. 323. (1931)†.
A. Fowler and W. M. Vaidya, *P.R.S.*, **132**, 310. (1931)†.

Most of the strong heads of the very extensive main system of bands are listed below. The v′, v″ values are from Fowler and Vaidya. Wave-lengths greater than 4800 are from Curtis and Tolansky, and other wave-lengths are those given by Fowler and Vaidya reduced by 0·2 A. Intensities for CS_2 flame are on a scale of 1 to 6.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
6165·8	1	9, 30	4651·1	4	3, 17	3321·0	1	3, 4
6102·3	2	8, 29	4609·8	5	2, 16	3290·5	3	2, 3
6039·1	2	7, 28	4563·0	4	1, 15	3259·7	2	1, 2
5980·8	1	6, 27	4523·3	2	0, 14	3244·5	3	3, 3
5962·2	3	9, 29	4478·6	4	2, 15	3215·9	2	2, 2
5900·7	4	8, 28	4433·4	6	1, 14	3203·0	2	4, 3
5840·6	4	7, 27	4394·8	2	0, 13	3171·3	2	3, 2
5783	2	6, 26	4354·8	2	2, 14	3160·9	1	5, 3
5769·5	3	9, 28	4310·8	6	1, 13	3143·5	1	2, 1
5710·1	4	8, 27	4274·2	3	0, 12	3132·2	3	4, 2
5651·6	4	7, 26	4193·6	6	1, 12	3101·3	1	3, 1
5596·4	3	6, 25	*4157·0	5	0, 11	3091·5	5	5, 2
5530·0	3	8, 26	4080·8	3	1, 11	3063·4	3	4, 1
5472·8	4	7, 25	*4045·6	6	0, 10	3054·7	3	6, 2
5418·8	4	6, 24	*3938·9	6	0, 9	3032·9	1	3, 0
5359·0	3	5, 23	3909·4	1	2, 10	3024·6	4	5, 1
5309·2	3	4, 22	*3837·1	6	0, 8	3017·8	2	7, 2
5249·7	5	6, 23	*3739·8	6	0, 7	2996·8	1	4, 0
5194·2	5	5, 22	3677·4	3	1, 7	*2989·5	4	6, 1
5145·4	4	4, 21	*3645·0	5	0, 6	2959·9	2	5, 0
5090·2	5	6, 22	3587·2	5	1, 6	*2954·0	4	7, 1
5036·2	6	5, 21	3555·6	3	0, 5	2926·4	2	6, 0
4989·5	6	4, 20	3500·3	5	1, 5	*2920·2	4	8, 1
4937	5	3, 19	3469·4	2	0, 4	2892·3	4	7, 0
4893·6	5	2, 18	3450·8	2	2, 5	2887·9	4	9, 1
4842·1	6	4, 19	3416·8	4	1, 4	*2860·0	3	8, 0
4790·6	6	3, 18	3386·8	1	0, 3	*2829·1	3	9, 0
4747·4	5	2, 17	3369·4	4	2, 4	2798·8	3	10, 0
4698·8	3	1, 16	3336·5	2	1, 3	2769·4	3	11, 0

* Fainter head to violet.

SH

Reference. M. N. Lewis and J. V. White, *P.R.*, **55**, 894. (1939).

3237 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Pi_i$

Analagous to the OH bands and degraded to the red. Obtained in absorption by passing repeated flashes from a source of continuum through a discharge tube in which HS radicals were formed by pulses of radio frequency current synchronized to precede the flashes by a very short interval. Many attempts to obtain the system in emission have failed.

	Heads λ (I)		
v′, v″	R_1	Q_1	Q_2
0, 0	3236·6 (8)	3240·7 (7)	3279·1 (4)

SO

Occurrence. In almost all sources containing sulphur and oxygen. The bands are strongly developed in vacuum tubes containing sulphur dioxide, especially with a mildly-condensed discharge.
Appearance. Degraded to red. Single-headed bands with rather extended rotational structure. See Plate 6.
Transition. $^3\Sigma \rightarrow {}^3\Sigma$, ground state.
References. V. Henri and F. Wolff, *Jour. Phys. Rad.*, **10**, 81. (1929)†.
E. V. Martin, *P.R.*, **41**, 167. (1932)†,

Measurements of strong bands by Martin ; weak bands by Henri and Wolff. Intensities by Henri and Wolff.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3941·6	0	1, 14	3271·0	10	0, 8	2699·1	4	2, 3
3903·6	1	0, 13	3247·5	1	2, 9	2664·8	5	1, 2
3862·7	3	2, 14	3164·8	10	0, 7	2655·6	1	3, 3
3811·8	5	1, 13	3064·1	10	0, 6	2630·1	1	0, 1
3761·6	2	0, 12	3007·9	2	1, 6	2622·2	3	2, 2
3724·7	3	2, 13	2968·5	5	0, 5	2589.0	2	1, 1
3676·2	7	1, 12	2915·4	4	1, 5	2581·1	1	3, 2
3628·2	3	0, 11	2877·7	4	0, 4	2555·5	0	0, 0
3548·7	6	1, 11	2827·4	8	1, 4	2548·6	2	2, 1
3502·1	4	0, 10	2791·3	2	0, 3	2516·4	1	1, 0
3428·1	3	1, 10	2779·8	1	2, 4	2510·4	1	3, 1
3383·1	6	0, 9	2744·0	6	1, 3	2477·7	1	2, 0
3314·8	1	1, 9	2708·6	1	0, 2	2442·0	1	3, 0

SO_2

Sulphur dioxide has a very readily observed absorption band system in the region of 3000 A. With relatively thick layers of gas the absorption extends from 4000 A. to 2000 A., being probably composed of two or more systems. In emission bands have been observed in three regions of the ultra-violet, and in addition there is a weak system of bands observed in the afterglow in the violet.

SO_2 (*contd.*)

ABSORPTION SPECTRUM, MAIN SYSTEM

The strong part of this system extends from 3200 to 2600 A. By using a metre or so of gas at atmospheric pressure, absorption bands can be observed as far as 4000 A.
Appearance. Degraded to the red. Fairly closely-spaced bands in the region 3200–2750. Below 2750 A. the bands become diffuse, and the longer wave-length end of the system also consists of narrow headless bands. See Plate 6.
Analysis. The bands are definitely due to the molecule SO_2 and many observers have published what they state to be an analysis of the system, but the agreement between the various authors is poor and it appears that very little reliance can be placed in any existing analysis. That of Clements, who studied the bands at various temperatures, is perhaps the most likely solution.
References. J. H. Clements, *P.R.*, **47**, 224. (1935).
W. C. Price and D. M. Simpson, *P.R.S.*, **165**, 272. (1938)†.

The following are the wave-lengths of the maxima of the strongest bands ; these maxima are close to the heads, being usually less than 1 A. to the red of the head ; intensities are based on Clements quantitative measurements.

λ	I	λ	I	λ	I	λ	I
3190·9	1	3065·9	5	2906·5	8	2780·0	6
3181·1	1	3043·3	7	2900·9	5	2772·0	4
3173·0	1	3022·1	9	2887·7	9	2765·2	4
3167·0	1	3001·0	10	2868·9	8	2754·6	4
3159·0	2	2980·0	9	2852·0	9	2751·2	4
3151·8	2	2961·2	10	2832·3	8	2738·1	4
3131·3	3	2943·8	9	2818·1	7	2734·6	5
3129·5	?	2937·7	8	2815·5	7	2727·5	3
3108·4	3	2924·8	8	2797·0	8	2685·0	4
3087·7	4	2923·1	8	2789·4	7	2646·6	3

This system has also been observed in fluorescence by Lotmar (*Z.P.*, **83**, 765. (1933)) and is frequently observed in emission spectra of sulphur dioxide superposed, by self-absorption, on the continuous spectrum readily emitted by this molecule.

ABSORPTION SPECTRUM, OTHER BANDS

The following are the strongest absorption bands in the far ultra-violet ; the bands are degraded to the red ; measurements by B. N. Bhaduri. See also Price and Simpson.
λλ2348·0, 2326·5, 2323·9, 2303·5, 2295·5, 2276·2, 2257·5, 2241·5, 2238·6, 2222·9, 2204·5, 2186·6, and 2168·3.

EMISSION SPECTRUM

Occurrence. In mild uncondensed discharges through flowing SO_2.
References. W. H. Bair, *Astrophys. J.*, **52**, 301. (1920).
T. Chow, *P.R.*, 44, 638. (1933).
B. N. Bhaduri, *Ph. D. Thesis*, London.

The emission spectrum is best considered in three regions ; the measurements are by Bhaduri.

SO_2 (*contd.*)

A. Region 4340–2700 A.

Very complex mass of bands degraded to the red, strongest heads: λλ3691·8, 3668·7, 3557·7, 3359·2, 3343·4, 3228·7, 3158·1, 3122·0.

B. Region 2640–2350 A.

A strong group of bands between 2640 and 2490 A., and weaker bands extending to 2350 A.; degraded to longer wave-lengths. Strongest heads: λλ2622·2, 2606·6, 2595·8, 2585·5, 2579·7, 2568·0, 2558·6, 2552·6, 2541·8, 2532·6, 2526·5, 2516·2, 2507·3, 2493·0, 2482·8, 2458·8, 2411·4, 2396·1. See Plate 6.

C. Region 2343–2170 A.

A relatively simple group of close double-headed bands degraded to the red. Strong bands :—

λ	I	λ	I
2342·6	5	2281·1	2
2321·9	6	2261·8	4
2302·0	5	2243·6	4

Afterglow Spectrum

Occurrence. In afterglow of discharge through SO_2.

Appearance. Narrow headless bands often occurring in pairs.

Reference. A. G. Gaydon, *P.R.S.*, **146**, 901. (1934)†.

Maxima of strongest bands: λλ4461·0, 4361·1, 4265·3, 4244·6, 4152·9, 4066·5, 4048·3, 3963·7, 3883·0.

Sb_2

Two systems in the ultra-violet have been observed in absorption. All the bands are degraded to the red.

References. S. M. Naudé, *P.R.*, **45**, 280. (1934).
J. Genard, *P.R.*, **44**, 468. (1933).
G. Nakamura and T. Shidei, *Japan Jour. Phys.*, **10**, 11. (1935).

The following measurements are by Nakamura and Shidei :—

System II, λλ2333–2178

Strongest bands :—

λ	I	v′, v″
2272·2	4	0, 3
2258·5	4	0, 2
2244·9	5	0, 1
2222·8	7	2, 1
2209·4	5	2, 0

System III, λλ2168–2048

Strongest bands: λλ2138·6, 2126·8, 2115·0, 2104·3.

Nakamura and Shidei's System I, consisting of bands around 2900 A., appears to be due to SO_2.

SbBi

A system of bands λλ2528–2399 have been observed in absorption by a mixture of antimony and bismuth vapours. They are degraded to the red.

Reference. G. Nakamura and T. Shidei, *Japan Jour. Phys.*, **10**, 11. (1935)†.

The following are the strongest bands :—

λ	I	v′, v″
2514·0	2	0, 4
2500·6	4	0, 3
2487·4	4	0, 2
2473·7	4	0, 1
2462·2	2	1, 1
2460·4	3	0, 0
2449·0	2	1, 0

SbCl

Reference. I. Hudes, *P.R.*, **52**, 1256. (1937).

A band system in the region 4600 to 4200 A. has been observed by Hudes in active nitrogen. The following formulæ are given :—

$$\nu_1 = 19146{\cdot}1 + 367{\cdot}7\,u' - 2{\cdot}61\,u'^2 - 483{\cdot}3\,u'' + 1{\cdot}43\,u''^2$$
$$\nu_2 = 21896{\cdot}6 + 364{\cdot}2\,u' - 2{\cdot}19\,u'^2 - 492{\cdot}7\,u'' + 4{\cdot}46\,u''^2$$

SbF

Occurrence. Antimony fluoride in active nitrogen.

Reference. G. D. Rochester, *P.R.*, **51**, 486. (1937)†.

System A, λλ5200–3600

Degraded to the red. Strongest bands: λλ4406·6 (0, 2), 4292·6 (0, 1), 4183·6 (0, 0), 4111·9 (1, 0), and 4043·2 (2, 0).

System B, λλ2700–2500

Degraded to shorter wave-lengths. Strongest heads : λλ2714, 2630 and 2572.

Systems C_1 and C_2, λλ2430–2200

Degraded to shorter wave-lengths. No measurements available.

SbN

Reference. N. H. Coy and H. Sponer, *P.R.*, **53**, 495 (A.). (1938).

Bands, observed in a discharge tube, to the red of λ2890.

SbO

Occurrence. Metallic antimony in carbon arc in air.

Appearance. Four systems of bands all degraded to the red.

Reference. B. C. Mukherji, *Z.P.*, **70**, 552. (1931)†.

The following tables give the strongest bands as listed by Mukherji ; no intensities are given, but the bands listed are those which are strong in his plates :—

SbO (*contd.*)

SYSTEM A, λλ3672–3337

λ	v′, v″
3672·0	0, 3
3568·4	0, 2
3469·2	0, 1
3402·0	1, 1
3374·0	0, 0

SYSTEM B, λλ4004–3552

λ	v′, v″
3894·0	0, 1
3775·4	0, 0
3696·5	1, 0
3622·3	2, 0

SYSTEM C, λλ4757–3786

λ	v′, v″
4424·4	0, 2
4273·2	0, 1
4130·6	0, 0
4035·0	1, 0
3945·8	2, 0

SYSTEM D, λλ6019–4398

λ	v′, v″	λ	v′, v″
5506·5	0, 3	4795·9	2, 1
5277·8	0, 2	4673·4	3, 1
5126·7	1, 2	4619·0	2, 0
5065·9	0, 1	4504·6	3, 0
4926·4	1, 1		

ScO

A strong band system in the orange and a weaker system in the blue-green have been attributed to scandium oxide.

Occurrence. Scandium salts in an arc.

Reference. W. F. Meggers and J. A. Wheeler, *Bur. Stand. J. Res.*, **6**, 239. (1931)†.

ORANGE SYSTEM, λλ7300–5740

Appearance. Degraded to longer wave-lengths. Rather widely-spaced double double-headed bands. Long sequences.

Transition. A $^2\Pi \rightarrow$ X $^2\Sigma$, ground state.

The following are the strong heads at the beginning of the three principal sequences. Intensities are based on Meggers and Wheeler's, but reduced to a scale of 10.

ScO (*contd.*)

λ	I	v′, v″	λ	I	v′, v″
5736·8	1	1, 0 i Q	6017·1	6	0, 0 i R
5764·4	1	1, 0 ii R	6036·2	10	0, 0 i Q
5772·7	2	2, 1 i Q	6064·3	7	0, 0 ii R
5809·8	3	3, 2 i Q	6072·6	8	1, 1 i Q
5811·6	2	2, 1 ii Q	6079·3	8	0, 0 ii Q
5847·7	3	4, 3 i Q	6101·9	5	1, 1 ii R
5849·1	3	3, 2 ii Q	6109·9	6	2, 2 i Q
5887·4	3	4, 3 ii Q	6116·0	6	1, 1 ii Q
5928·1	2	5, 4 ii Q			
5959·0	1	6, 5 ii R	6437·1	1	0, 1 ii R
5968·5	1	6, 5 ii Q	6446·2	5	1, 2 i Q
			6495·9	2	1, 2 ii Q
			6525·6	2	3, 4 i Q

BLUE-GREEN SYSTEM, λλ5330–4500

Appearance. Close double-headed bands (separation 0·3 A.) degraded to the red.

Transition. $B\,^2\Sigma \rightarrow X\,^2\Sigma$, ground state.

The following are the first (R) heads of the strong bands :—

λ	I	v′, v″
5096·7	4	0, 1
4857·8	5	0, 0
4707·0	2	2, 1
4672·6	2	1, 0
4571·8	2	4, 2
4536·6	1	3, 1
4502·8	1	2, 0

Se_2

A very extensive group of bands has been attributed to selenium Se_2. These bands have been analysed into several systems, but Asundi and Parti have recently expressed the opinion that all the absorption and emission bands observed in discharge tubes belong to one extensive system which, however, shows marked irregularities due presumably to perturbations.

There is also a weak system between 6800 and 6000 A. which has been observed in a high-frequency electrodeless discharge by Rosen and Monfort.

Absorption bands in the ultra-violet observed by Moraczewska are attributed to selenium oxide by Asundi and Parti.

References. B. Rosen, *Z.P.*, **43**, 69. (1927).
M. Moreczewska, *Z.P.*, **62**, 270. (1930).
T. E. Nevin, *Phil. Mag.*, **20**, 347. (1935).
B. Rosen and F. Monfort, *Bull. Acad. Roy., Belgium*, **22**, 215. (1936).
R. K. Asundi and Y. P. Parti, *Indian Acad. Sci. Proc.*, **6A**, 207. (1937)†.

MAIN SYSTEM, α

Occurrence. In absorption and in discharge tubes; the bands have also been observed in fluorescence by Rosen.

Appearance. Degraded to longer wave-lengths. In absorption the strong part of the system consists of regularly-spaced bands, but in emission the bands occur in waves.

Se_2 *(contd.)*

The following are the strongest bands observed by Nevin in absorption :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3545·4	7	14, 3	3432·0	9	13, 0	3337·1	9	17, 0
3530·4	7	11, 1	3407·1	9	14, 0	3315·3	9	18, 0
3483·5	9	11, 0	3383·2	9	15, 0	3293·9	9	19, 0
3457·3	9	12, 0	3359·7	9	16, 0	3274·0	8	20, 0

The following are the strongest bands observed by Asundi and Parti in emission :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5779·6	5	13, 33	5400·9	4	11, 28	4216·9	5	9, 12
5730·8	4	8, 29	5388·3	4	4, 23	4168·6	4	4, 8
5719·3	4	4, 26	5144·2	5	12, 26	4148·9	4	6, 9
5638·0	4	12, 31	5141·0	4	15, 28	4103·9	4	7, 9
5622·3	5	8, 28	5134·3	4	1, 18	4041·7	4	7, 8
5606·8	4	11, 30	4819·6	4	3, 16	4002·9	5	8, 8
5591·3	4	7, 27	4591·8	4	7, 16	3980·7	8	7, 7
5576·0	4	10, 29	4586·3	4	10, 18	3943·5	7	8, 7
5518·5	4	8, 27	4303·0	7	7, 12	3907·2	6	9, 7
5502·4	5	11, 29	4258·0	4	8, 12	3885·9	4	8, 6
5471·4	5	10, 28	4255·1	7	5, 10	3849·9	5	9, 6

$SeBr_2$

Diffuse bands have been observed in absorption. Maxima at λλ5402, 5334, 5267, 5205, 5138*, 5075, 5017 and 4963.

* Strongest band.

Reference. M. Wehrli, *Helvetica Phys. Acta,* **9**, 329. (1936).

$SeCl_2$

Diffuse bands have been observed in absorption. Maxima at λλ5974, 5854, 5742, 5634, 5531, 5439, 5346, 5257, 5179, 5084, 5031, 4960, 4885, 4806, 4735, and 4659.

Reference. M. Wehrli, *Helvetica Phys. Acta,* **9**, 637. (1936).

SeO

Occurrence. Aqueous solution of SeO_2 introduced into a flame.

Appearance. Degraded to the red. A strong v′ = 0 progression and a few weaker bands of the v′ = 1 progression. The bands show a strong head and a weaker head on the shorter wave-length side.

Reference. R. K. Asundi, M. Jan-Khan and R. Samuel, *P.R.S.*, **157**, 28. (1936)†.

The following are the heads as recorded by Asundi, Jan-Khan and Samuel ; the vibrational analysis given by them is only tentative as the origin of the system is uncertain :—

λλ3945, 3821*, 3701*, 3590*, 3582, 3484*, 3476, 3421, 3415, 3382, 3324, 3317, 3285, 3231.

* Relatively strong band.

There are also some weaker bands in the region 2900–2500 A., but these may be due to SeO_2.

SeO_2

Occurrence. In absorption.
Appearance. A complex system of narrow diffuse bands degraded to the red.
Reference. See SeO.

The system extends from 3158 to 2417 A. A large number of bands are listed by Asundi, Jan-Khan and Samuel of which the following are indicated as being relatively strong: λλ3032·8, 3008·9, 2986·5, 2972·8, 2963·6, 2950·9, 2917·2, 2915·7, 2895·6, 2894·3, 2851·4, 2841·3, 2788·3, 2769·5, 2748·6, 2738·3, 2731·1, 2721·0, 2719·4, 2690·0, 2673·8, 2665·8, 2644·7, 2636·7, 2629·3, 2600·4, 2593·3, 2584·5, 2569·1, 2557·0, 2542·6, 2536·4, 2533·9, 2495·3, and 2493·2.

SiBr

Occurrence. Discharge through streaming $SiBr_4$ vapour.
Appearance. Degraded to shorter wave-lengths. Bands in region 3233–2875 A.
Transition. Probably $^2\Sigma \rightarrow {}^2\Pi$, ground state.
Reference. W. Jevons and L. A. Bashford, *Proc. Phys. Soc.*, 49, 554. (1937).

The strongest bands only are listed below; (i) and (ii) refer to the two components of the system :—

λ	I	v′, v″	λ	I	v′, v″
3086·8	7	0, 2 (i)	3008·8	10	0, 0 (i)
3047·7	9	0, 2 (ii)	2958·7	7	1, 1 (ii)
3047·3	9	0, 1 (i)	2958·2	7	1, 0 (i)
3009·2	8	0, 1 (ii)	2922·0	7	1, 0 (ii)

SiCl

Occurrence. Discharge through streaming $SiCl_4$ vapour.
Appearance. Degraded to shorter wave-lengths. Three systems in regions 2942, 2436 and 2232 A.
Transitions. Three excited states B, C, and D to ground state X, which is probably $^2\Pi$.
Reference. W. Jevons, *Proc. Phys. Soc.*, 48, 563. (1936).

λ 2942 System

The following wave-lengths are for the P heads, i and ii indicating each sub-band. The Q heads lie about 0·6 A. to the violet.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3117·8	1	1, 5 i	3020·5	6	1, 3 i	2942·2	8	0, 0 i
3097·5	0	1, 5 ii	3017·6	6	0, 2 ii	2924·4	8	0, 0 ii
3085·6	2	0, 3 i	3001·7	4	1, 3 ii	2882·9	8	1, 0 i
3068·7	2	1, 4 i	2988·8	8	0, 1 i	2865·8	8	1, 0 ii
3065·8	3	0, 3 ii	2973·5	4	1, 2 i	2826·1	7	2, 0 i*
3049·3	2	1, 4 ii	2970·4	8	0, 1 ii	2809·7	10	2, 0 ii*
3036·6	4	0, 2 i	2955·0	3	1, 2 ii	2772·0	7	3, 0 i*

* These bands may not belong to this system.

SiCl (*contd.*)

λ2436 System. P heads, i and ii indicating each sub-band.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
2601·5	1	0, 5 i	2521·0	1	0, 3 ii	2424·4	3	0, 0 ii
2588·3	1	0, 5 ii	2500·3	4	0, 2 i	2416·2	2	1, 1 ii
2567·3	1	0, 4 i	2488·2	6	0, 2 ii	2396·7	6	1, 0 i
2557·5	1	1, 5 i	2467·8	6	0, 1 i	2385·6	5	1, 0 ii
2555·5	2	0, 4 ii	2456·0	7	0, 1 ii	2359·1	1	2, 0 i
2544·3	1	1, 5 ii	2435·9		0, 0 i	2348·6	0	2, 0 ii
2533·4	4	0, 3 i	2437·7	2	1, 1 i			

λ2232 System. P heads, i and ii indicating each sub-band.

λ	I	v′, v″	λ	I	v′, v″
2341·1	0	0, 4 i	2258·4	5	0, 1 i
2313·1	1	0, 3 i	2247·7	5	0, 1 ii
2285·5	2	0, 2 i	2231·5	4	0, 0 i
2274·7	2	0, 2 ii	2221·2	4	0, 0 ii

SiF

The spectrum of SiF extends from the red to the far ultra-violet and the bands are very numerous. Johnson and Jenkins divided the bands into several systems denoted by the Greek letters α, β, γ, δ, ϵ, ζ, and η. Some of these systems have since been related by Asundi and Samuel.

Occurrence. In discharge through SiF_4.

Appearance. Very complicated systems. Good photographs are reproduced by Johnson and Jenkins.

Transitions. α system, $^2\Pi \rightarrow {}^2\Pi$, ground state.
β system, B $^2\Sigma \rightarrow {}^2\Pi$, ground state.
γ system, C $^2\Sigma \rightarrow {}^2\Pi$, ground state.

References. R. C. Johnson and H. G. Jenkins, *P.R.S.*, **116**, 327. (1927)†.
R. K. Asundi and R. Samuel, *Proc. Indian Acad. Sci.*, **3**, 346. (1936).

Only a few of the strongest heads are listed below. R, V, and M denote band degraded to longer or shorter wave-lengths or maximum of headless band respectively. Intensities reduced to scale of 10. The β and γ bands have close double heads.

λ	I	v′, v″	system.	λ	I	v′, v″	system
6594 V	3		ζ	3363 M	10		η
6492 V	5		ζ	3346 M	10		η
6416 V	5		ζ	3042·4 V	3	0, 2 P i	β
6397 V	5		ζ	3027·5 V	3	0, 2 P ii	β
6270 V	2		ζ	2967·1 V	6	0, 1 P i	β
4850·5 R	3	2, 5	α	2952·8 V	6	0, 1 P ii	β
4531·6 R	5	3, 4	α	2894·4 V	6	0, 0 P i	β
4495·8 R	5	2, 3	α	2880·8 V	6	0, 0 P ii	β
4462·0 R	4	1, 2	α	2813·0 V	4	1, 0 P i	β
4430·2 R	5	0, 1	α	2800·0 V	4	1, 0 P ii	β
4400·5 R	5	4, 4	α	2652·8 V	3	0, 2 Q i	γ
4368·2 R	10	3, 3	α	2641·4 V	3	0, 2 Q ii	γ
4334·4 R	4	2, 2	α	2595·1 V	5	0, 1 Q i	γ
4270·2 R	4	0, 0	α	2584·3 V	5	0, 1 Q ii	γ
4229·7 V	3		ϵ	2539·2 V	7	0, 0 Q i	γ
4183·3 V	4		ϵ	2528·9 V	7	0, 0 Q ii	γ
4011·8 V	4		ϵ				

SiH

References. G. D. Rochester, *Z.P.*, **101**, 769. (1936)†.
C. V. Jackson, *P.R.S.*, **126**, 373. (1930)†.

4142 A. System, $^2\Delta \rightarrow {}^2\Pi$, Ground State

Complex bands degraded to the red. Obtained in silicon arc in hydrogen, in hydrogen discharge tubes (silicon from glass walls) and in sun-spots.

v′, v″	Origins	Heads
0, 0	4126·6	4128 Q_1
0, 0	4147·8	4142·2 Q_2
1, 1	—	4184 Q_1
1, 1	—	4198·6 Q_2

SiN

There are two band systems attributed to this molecule, a strong system λλ5260–3786 and a weak system λλ5620–3188.

Strong System

Occurrence. Silicon tetrachloride vapour in active nitrogen.
Appearance. Degraded to red. Single-headed.
Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.
References. W. Jevons, *P.R.S.*, **89**, 187. (1913).
F. A. Jenkins and H. de Laszlo, *P.R.S.*, **122**, 105. (1929).

The following table is compiled from the above references. Wave-lengths of R heads. Intensities as given by Jevons.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4947	1	5, 8	4345·4	2	1, 2	4050·7	8	4, 3
4797	2	7, 9	4317·6	5	6, 6	4032·0	4	8, 6
4748·7	3	6, 8	4277·0	5	5, 5	4016·8	6	3, 2
4705·1	4	5, 7	4260·4	2	9, 8	3989·9	4	7, 5
4664·3	5	4, 6	4239·1	9	4, 4	3985·8	5	2, 1
4629·2	3	3, 5	4211·9	4	8, 7	3957·7	2	1, 0
4618·1	2	8, 9	4204·1	10	3, 3	3949·8	4	6, 4
4569·8	4	7, 8	4172·1	6	2, 2	3911·8	4	5, 3
4524·3	5	6, 7	4168·2	4	7, 6	3814·0	2	2, 0
4482·4	6	5, 6	4143·1	3	1, 1			
4443·1	8	4, 5	4126·6	8	6, 5			
4406·9	8	3, 4	4116·8	1*	0, 0			
4360·7	3	7, 7	4087·4	8	5, 4			

* This intensity is probably too low.

Weak System

Occurrence. Silicon tetrachloride vapour in active nitrogen.
Appearance. Degraded to red. Double-headed, separation 27 cm.$^{-1}$
Transition. Perhaps $^2\Pi \rightarrow {}^2\Pi$.
Reference. R. S. Mulliken, *P.R.*, **26**, 319. (1925).

In the following table the strongest bands listed by Mulliken are given. Intensities have been increased to a scale of 5. Only the shorter wave-length head is listed here.

SiN (*contd.*)

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
5555·2	2	4, 12	4877·6	2	1, 7	3744·1	2	3, 2
5492·1	2	3, 11	4834·7	2	4, 9	3698·4	1	2, 1
5235·0	3	3, 10	4463·6	2	1, 5	3607·8	2	3, 1
5172·6	5	2, 9	3994·7	4	2, 3	3535·0	4	4, 1
4937·4	2	2, 8	3841·6	1	2, 2	3400·4	1	4, 0

SiO

Occurrence. In flames into which $SiCl_4$ is introduced, in discharge through $SiCl_4$ vapour mixed with oxygen, and strongly in arc.

Appearance. Degraded to red. Single-headed. See Plate 1.

Transition. $^1\Pi \rightarrow {}^1\Sigma$, ground state.

Reference. W. Jevons, *P.R.S.*, **106**, 174. (1924).

The following measurements are by Jevons. Intensities I_d and I_f are for discharge tube and flame respectively, the latter being from de Gramont and de Watteville.

λ	I_d	I_f	v′, v″
2925·3	2		4, 10
2898·4	3		3, 9
2871·6	4		2, 8
2845·7	2		1, 7
2832·2	1		4, 9
2820·0			0, 6
2806·3	8		3, 8
2780·5	7	6	2, 7
2755·0	6	6	1, 6
2730·1	2		0, 5
2718·8	4		3, 7
2693·7	9	7	2, 6
2669·0	9	8	1, 5
2644·8	4	4	0, 4
2636·0			3, 6
2611·3	4		2, 5
2587·1	5	8	1, 4
2563·8	5	8	0, 3
2509·9	4	3	1, 3

λ	I_d	I_f	v′, v″	
2486·8	6	10	0, 2	
2481·9	2	3	3, 4	
2459·0	3	4	2, 3	
2436·3	3		1, 2	
2413·8	7	8	0, 1	
2410·2			3, 3	
2387·9	5	3	2, 2	
2365·7	6	1	1, 1	
2364·5		4	4, 3	
2344·3	5	4	0, 0	
2342·4	1	4	3, 2	
2298·9	6	2	1, 0	4, 2
2277·2	1	1	3, 1	
2255·9	4		2, 0	
2236·3	2	1	4, 1	
2215·4	2	0	3, 0	
2197·4	0		5, 1	
2176·6	1		4, 0	

SiO_2?

Occurrence. These bands have been recorded by Cameron as occurring in a silicon arc in oxygen at reduced pressure. They have also been observed by Pankhurst using a heavy-current discharge through a silica vacuum tube.

Appearance. A strong group of bands between 4215 A. and 4300 A., consisting of bands degraded in both directions and rather diffuse maxima of intensity ; weaker bands, mostly degraded to the red, throughout the violet region.

References. W. H. B. Cameron, *Phil. Mag.*, **3**, 110. (1927)†.
R. C. Pankhurst, *Proc. Phys. Soc.*, **52**, 707. (1940)†.

These bands are of complex structure and it is unlikely that they are emitted by a diatomic molecule. The conditions of their occurrence suggest SiO_2 as the emitter.

SiO_2 (*contd.*)

The following measurements are by Pankhurst. The letters R, V, or M, that the band is degraded to longer or shorter wave-lengths, or that the measurement is of the maximum of intensity of a headless structure, respectively.

λ	I	λ	I	λ	I
4468·5 R	4	4262·8 R	6	4022 M	3
4466·6 R	3	4256·6 R	8	3972 M	4
4417·3 R ?	3	4254·4 R	7	3922 M	4
4408 R ?	4	4252·4 V	6	3832·9 R	6
4392·7 R	2	4240 M	10	3791·4 R	2
4283 M	9	4235·5 V	10	3776·9 R	3
4274·5 R	4	4228·5 V	9	3713·5 R	2
4269·6 R	4	4071·7 R	1		

SiS

Occurrence. High current-density discharge through quartz tube containing sulphur sulphide. A few bands of the strong system have also been obtained in absorption.
Reference. R. F. Barrow and W. Jevons, *P.R.S.*, **169**, 45. (1938)†.

STRONG SYSTEM, λλ3959–2585

Appearance. Degraded to the red. Apparently single-headed bands. The following are the strong bands :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3506·3	4	3, 11	3244·2	5	2, 7	2883·2	8	1, 1
3471·8	4	5, 12	3221·8	8	1, 6	2863·7	8	0, 0
3447·4	4	4, 11	3149·0	7	1, 5	2822·7	9	1, 0
3423·6	5	3, 10	3127·7	8	0, 4	2783·2	9	2, 0
3399·7	5	2, 9	3078·8	7	1, 4	2764·7	6	4, 1
3343·4	5	3, 9	3057·9	9	0, 3	2745·3	8	3, 0
3320·1	6	2, 8	2990·8	10	0, 2	2708·8	7	4, 0
3297·6	7	1, 7	2926·1	10	0, 1	2673·8	6	5, 0

WEAK SYSTEM, λλ6169–3491

Appearance. Degraded to the red. An extensive system of relatively weak bands, which are spaced at regular intervals.

SiSe

Occurrence. Heavy-current discharge through quartz tube containing aluminium selenide.
Appearance. Degraded to the red. Single-headed bands.
Reference. R. F. Barrow, *Proc. Phys. Soc.*, **51**, 267. (1939)†.

Strong bands :—

λ	I	v′, v″	λ	I	v′, v″
3406·0	7	1, 6	3145·3	9	0, 1
3342·2	9	1, 5	3106·4	9	1, 1
3323·7	8	0, 4	3051·8	8	1, 0
3262·4	10	0, 3	3015·8	7	2, 0
3203·0	10	0, 2	2981·1	6	3, 0

SiTe

Occurrence. Heavy current through quartz tube containing aluminium and tellurium.
Appearance. Degraded to the red. Single-headed bands.
Reference. R. F. Barrow, *Proc. Phys. Soc.*, **51**, **45**. (1939)†.

Strong bands :—

λ	I	v′, v″	λ	I	v′, v″
3763·9	8	1, 5	3556·1	10	0, 1
3745·2	9	0, 4	3514·3	10	1, 1
3680·3	9	0, 3	3456·2	8	1, 0
3617·3	10	0, 2	3417·0	7	2, 0

SmO

Occurrence. Samarium salts in oxy-hydrogen flame.
Reference. G. Piccardi, *Rend. Accad. Linc.*, **21**, 589. (1935).

The following are the strongest heads :—

λ	I	λ	I
6570·1	6	6485·5	7
6557·2	8	6349·5	8
6533·5	9	6034·4	6
6510·9	10	5822·4	7

SnBr

Occurrence. Heavy-current discharge through flowing tin tetrabromide vapour.
Reference. W. Jevons and L. A. Bashford, *Proc. Phys. Soc.*, **49**, 554. (1937)†.

VIOLET SYSTEM, λλ4255–3709

Appearance. Degraded to the red.
Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.

Strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
4196·5	6	0, 3 i	3820·8	6	0, 2 ii
4153·9	8	0, 2 i	3798·4	7	1, 2 ii
4112·1	10	0, 1 i	3785·8	7	0, 1 ii
4070·7	10	0, 0 i	3750·8	8	0, 0 ii
3833·7	6	1, 3 ii	3729·4	6	1, 0 ii

ULTRA-VIOLET SYSTEM, λλ3428–3021

Appearance. Degraded to shorter wave-lengths. Two progressions which look rather like sequences.
Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.

Strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
3372·0	4	0, 4 i	3112·2	4	0, 4 ii
3344·6	5	0, 3 i	3089·2	5	0, 3 ii
3317·2	6	0, 2 i	3066·4	6	0, 2 ii
3290·4	7	0, 1 i	3043·6	7	0, 1 ii
3263·7	*	0, 0 i	3021·1	4	0, 0 ii

* Masked by Sn line 3262·33.

SnCl

There are two band systems in the ultra-violet, λλ3910–3486 and λλ3405–2830, and a strong continuum from λ4900 to λ3950.

Occurrence. Uncondensed discharge through tin tetrachloride vapour.

References. W. Jevons, *P.R.S.*, **110**, 365. (1926)†.
W. F. C. Ferguson, *P.R.*, **32**, 607. (1929).

λλ3910–3486 System

Appearance. Degraded to red. Two strong sequences.

Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.

Heads of strong bands :—

λ	I	v′, v″	λ	I	v′, v″
3786·3	2	3, 3 i	3511·2	1	3, 3 ii
3776·6	5	2, 2 i	3502·5	2	2, 2 ii
3767·3	8	1, 1 i	3494·7	8	1, 1 ii
3758·5	10	0, 0 i	3487·8	10	0, 0 ii

λλ3405–2830 System

Appearance. Degraded to shorter wave-lengths. Strong $SnCl^{35}$ heads with weaker $SnCl^{37}$ heads visible in a few bands.

Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.

Heads of strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
3271·5	5	0, 2 i	3004·5	6	0, 1 ii
3234·4	7	0, 1 i	2973·4	8	0, 0 ii
3197·8	7	0, 0 i	2966·3	3	1, 1 ii
3154·5	7	1, 0 i	2959·3	5	2, 2 ii
3112·4	5	2, 0 i	2935·8	10	1, 0 ii
3105·2	4	3, 1 i	2899·4	7	2, 0 ii
3036·4	4	0, 2 ii	2893·0	5	3, 1 ii

SnF

Occurrence. In absorption.

Appearance. Four band systems, all degraded to shorter wave-lengths, and two regions of continuous absorption.

Reference. F. A. Jenkins and G. D. Rochester, *P.R.*, **52**, 1135. (1937)†.

The P heads of the strong bands are given below. No intensities are available, but the high-frequency components of the doublet systems (denoted by ii below) are stated to be the stronger.

System A $^2\Sigma \leftarrow$ X $^2\Pi$, Ground State, λλ3260–2660

This is the strongest system. Close double-headed bands, separation about 1A.

λ	v′, v″
3199·7	0, 1 i
3141·2	0, 0 i
3076·2	1, 0 i
3020·7	0, 2 ii
2978·2	0, 1 ii
2969·4	1, 2 ii
2927·9	0, 0 ii
2871·4	1, 0 ii
2817·6	2, 0 ii

SnF (*contd.*)

SYSTEM B $^2\Delta \leftarrow$ X $^2\Pi$, λλ2635–2556

Close double-headed bands. System partly obscured by continuum.

λ	v′, v″
2635·4	0, 1
2595·5	0, 0
2556·3	1, 0

SYSTEM C $^2\Pi \leftarrow$ X $^2\Pi$, λλ2350–2100

This is a weak system of single-headed bands.

λ	v′, v″
2348·2	1, 0 i
2222·8	0, 1 ii
2194·7	0, 0 ii
2162·5	1, 0 ii

SYSTEM D $^2\Delta \leftarrow$ X $^2\Pi$, λλ2300–2060

A strong system of close double-headed bands.

λ	v′, v″	λ	v′, v″
2296·7	0, 1 i	2184·3	0, 1 ii
2266·3	0, 0 i	2157·1	0, 0 ii
2236·1	1, 1 i	2129·3	1, 0 ii

CONTINUA

E $\leftarrow$ X $^2\Pi$, λ2500–2370.

F $\leftarrow$ X $^2\Pi$. In far ultra-violet below 2100 A.

SnH

4050 A SYSTEM

Occurrence. Obtained by Watson and Simon from a tin arc in hydrogen at 5 atmospheres pressure.

Appearance. Complex bands degraded to the red.

Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.

Reference. W. W. Watson and R. Simon, *P.R.*, **55**, 358. (1939).

With low dispersion, heads are observed at 4054 A and 4447 A, followed by stronger heads at 4071 A and 4466 A. The latter are shown to be complex by high dispersion.

$^RQ_{21dc,cd}$	$R_{1dc,cd}$	Q_2	$^QR_{12}$
4071·3	4071·8	4466·6	4466·0
4071·4	4070·8		

The band is assumed to be the 0, 0 band of the system.

6095 A SYSTEM

Under similar conditions Watson and Simon observed a band to longer wave-lengths with heads at 6095 A, 6063 A, and 6022 A, accompanied by a weaker band with a head at 6214 A. Further bands to the red and infra-red are mentioned but on details are given.

SnO

Occurrence. In arcs and flames containing tin salts. Connelly used a high-tension discharge through a flame containing $SnCl_4$ vapour for the production of the main system, and Loomis and Watson used an arc at reduced pressure for their system.

References. F. C. Connelly, *Proc. Phys. Soc.*, **45**, 780. (1933)†.
F. W. Loomis and T. F. Watson, *P.R.*, **45**, 805. (1934).

The strongest system, A, lies in the violet and near ultra-violet, and two doubtful weaker systems B and C are also in the violet. Loomis and Watson's system is a little further to the ultra-violet.

Main System A, λλ4488–3072

Appearance. Degraded to red.
Transition. To ground state.

The strong bands only are listed. Intensities on scale of 8.

λ	I	v′, v″	λ	I	v′, v″
3691·4	5	0, 3	3388·3	6	0, 0
3585·4	7	0, 2	3323·4	7	1, 0
3484·5	8	0, 1	3262·4	6	2, 0
3415·8	5	1, 1	3205·8	4	3, 0

Systems B and C.

Degraded to red. Strong bands :—

System B			System C		
λ	I	v′, v″	λ	I	v′, v″
4217·7	3	0, 2	4411·4	3	0, 2
4079·1	3	0, 1	4302·9	3	1, 2
3978·7	2	1, 1	4262·3	3	0, 1

Loomis and Watson's System

Appearance. Degraded to red.
Transition. To ground state.

Strong bands only are listed. Intensities on a scale of 8.

λ	I	v′, v″	λ	I	v′, v″
3043·6	6	2, 6	2740·1	6	3, 2
2990·4	8	0, 4	2716·9	7	2, 1
2947·7	6	1, 4	2680·8	6	3, 1
2921·7	8	0, 3	2658·1	6	2, 0
2814·8	8	1, 2	2646·9	6	4, 1

SnS

Three systems, all degraded to the red, λλ4709–4183, 4033–3198, and 3325–2735, have been observed in absorption.

Reference. G. D. Rochester, *P.R.S*, **150**, 668. (1935)†.

SnSe

Three band systems, all degraded to the red, have been observed in absorption.

Reference. J. W. Walker, J. W. Straley and A. W. Smith, *P.R.*, **53**, 140. (1938).

SnSe (*contd.*)

The following are the strongest heads :—
System A, λλ5392·8, 5330·0, 5238·6.
System B, λλ4664·4, 4572·4, 4504·8, 4396·3.
System C, 3865·3, 3817·3.

SrBr

There are two systems attributed to SrBr, in the red and in the violet.

RED SYSTEM

Occurrence. In absorption and when strontium bromide is introduced into a flame. They do not appear strongly in an arc.

Appearance. Close marked sequences ; the bands appear to be degraded to shorter wave-lengths under low dispersion.

Transition. Probably $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. K. Hedfeld, *Z.P.*, **68,** 610. (1931).
O. H. Walters and S. Barratt, *P.R.S.*, **118,** 120. (1928).

The following list of measurements is compiled from the above sources. Intensities I_a and I_f are for absorption and emission in a flame respectively.

λ	I_a	I_f	Sequence
6924	0		
6800·2	10		
6763·6		0	0, 1 i
6666·7	10	10	0, 0 i
6605·4		0	0, 1 ii
6572·4		0	1, 0 i
6513·0	5	10	0, 0 ii
6422·8		0	1, 0 ii

VIOLET SYSTEM

Occurrence. In absorption and in a flame.

Appearance. Close sequences which appear to be degraded to longer wave-lengths with small dispersion.

References. O. H. Walters and S. Barratt, *P.R.S.*, **118,** 120. (1928).
C. M. Olmsted, *Zeit. f. wissen., Photographie*, **4,** 255. (1906).

The following measurements are by Walters and Barratt. Intensities I_a and I_f are for absorption and emission in a flame, the latter being by Olmsted.

λ	I_a	I_f	λ	I_a	I_f
4186	0	1	4053	10	6
4146	4	3	4019	2	3
4129	1	2	3992	0	1
4108	9	6	3945	5	
4090	3	3	3909	5	
4073	2	3			

SrCl

Occurrence. When strontium chloride is introduced into an arc or flame. Also in absorption.

References. K. Hedfeld, *Z.P.*, **68,** 610. (1931)†.
A. E. Parker, *P.R.*, **47,** 349. (1935).

SrCl (*contd.*)

There are two strong systems, in the red and violet respectively. Parker also reports some weaker bands in the red and orange.

RED SYSTEM, λλ6752–6232

Appearance. Degraded to violet. Close sequences.

Transition. Perhaps A $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Heads of strong sequences :—

λ	I	Sequence *
6755·6	3	0, 1 P_1
6744·7	5	Q_1
6619·9	5	0, 0 P_1
6613·7	10	Q_1
6482·9	4	1, 0 Q_1 and 0, 1 Q_2
6362·4	5	0, 0 P_2
6358·7	10	Q_2
6239·3	2	1, 0 Q_2

* The vibrational analyses made by Hedfeld and by Parker do not correspond exactly.

VIOLET SYSTEM, λλ4136–3852

Appearance. Degraded to red.

Transition. Perhaps B $^2\Pi \rightarrow {}^2\Sigma$, ground state.

No intensities given. The following are the Q heads of sequences, the R heads, which are presumably weaker, lie about 1 A to the violet :—,

λ		
4009·4	Q_1	head of (1, 2) band, the first observed member of the (0, 1) sequence.
3983·4	Q_2	head of (1, 2) band.
3961·6	Q_1	head of (0, 0) band and sequence.
3937·1	Q_2	,, ,, ,, ,, ,,
3918·3	Q_1	,, (1, 0) ,, ,, ,,
3894·0	Q_2	,, ,, ,, ,, ,,

WEAKER BANDS. These may be due to CaCl.

Heads of sequences :—

λ	Degraded
6462·0	V
6184·8	V
6070·3	R
6068·1	R
5934·1	R

SrF

Occurrence. When SrF_2 is introduced into carbon arc or flame. Also in absorption.

References. S. Datta, *P.R.S.*, **99**, 436. (1921)†.
R. C. Johnson, *P.R.S.*, **122**, 161. (1929).
A. Harvey, *P.R.S.*, **133**, 336. (1931)†.

There are three systems, in the red, yellow, and ultra-violet.

SrF (*contd.*)

RED SYSTEM

A $^2\Pi \rightarrow {}^2\Sigma$, ground state. Marked sequences. Appearance best shown by Datta's photographs.

Strongest heads of sequences :—

λ	Deg.	I	Sequence
6655·6	V	7	0, 0 P_{12}
6632·7	V	10	0, 0 Q_{12}
6527·6	V	7	0, 0 P_2
6512·0	V	10	0, 0 Q_2
6419·0	V	8	1, 0
6394·7	R		
6306·1	V	8	1, 0
6283·1	R		

YELLOW SYSTEM

B $^2\Sigma \rightarrow {}^2\Sigma$, ground state. Degraded to red.

(0, 0) sequence R head λ 5779·5

,, ,, Q ,, 5772·0

(1, 0) sequence, evenly spaced bands between λ5622 and 5670.

ULTRA-VIOLET SYSTEM

C $^2\Pi \rightarrow {}^2\Sigma$, ground state. Degraded to red. Heads of sequences at λλ3646·3 and 3712·4.

SrH

Reference. W. W. Watson, and W. R. Fredrickson, *P.R.*, **39**, 765. (1932).

7508 A. SYSTEM. $^2\Pi \rightarrow {}^2\Sigma$, GROUND STATE

Bands degraded to the violet. Obtained from strontium arc in hydrogen.

v′, v″	Heads	
0, 0	7508	P_1
	7505	$^PQ_{12}$
	7348·0	$^QP_{21}$
	7346·7	Q_2

7020 A SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$, GROUND STATE

Bands degraded to the violet. Obtained in strontium arc in hydrogen.

v′, v″	Heads	
0, 0	7018·1	P_1
	6984·7	P_2

OTHER SYSTEMS ?

Watson and Fredrickson note that in their experiments a dense grouping of lines appeared in the yellow-green and small groups at around 5800 A.

SrI

Band systems have been observed in the red and violet by Walters and Barratt who also report three faint bands in the ultra-violet.

References. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928)†.

C. M. Olmsted, *Zeit. f. wissen. Photographie*, **4**, 255. (1906).

SrI (*contd.*)

RED SYSTEM.

Occurrence. In absorption. Olmsted also speaks of bands in the orange in a flame source ; these may be the same.

Appearance. Degraded to the violet.

The following measurements are by Walters and Barratt :—

λ	I	λ	I
7094·0	2	6767·8	10
7011·0	10	6691·5	8
6930·2	10	6662·3	8
6847·7	10	6177·3	4

VIOLET SYSTEM

Occurrence. In absorption, when strontium iodide is introduced into a flame, and probably in arc sources.

Appearance. Degraded to the red. Marked close sequences. The following measurements of the heads of the sequences are by Walters and Barratt. Intensities I_a and I_f are for absorption and emission in a flame respectively, the latter being by Olmsted.

λ	I_a	I_f	λ	I_a	I_f
4482	0	4	4339	2	4
4447	4	5	4307	6	6
4412	10	6	4276	1	2
4381	1	4			

ULTRA-VIOLET

Three weak bands λλ3439, 3406, and 3378, degraded to shorter wave-lengths, were observed in absorption.

SrO

Occurrence. When strontium salts are introduced into a carbon arc burning in air or into a flame.

Appearance. Degraded to red. Two systems, in the blue, and in the ultra-violet.

Reference. P. C. Mahanti, *P.R.*, **42**, 609. (1932) †.

Only the strong bands listed by Mahanti are given below. The intensities are on a scale of 6.

BLUE SYSTEM

λ	I	v′, v″	λ	I	v′, v″
4692·7	5	2, 7	4399·6	6	0, 3
4672·6	4	1, 6	4302·7	4	1, 3
4652·4	3	0, 5	4281·0	5	0, 2
4564·8	5	2, 6	4189·1	4	1, 2
4544·1	5	1, 5	4167·2	5	0, 1
4523·3	4	0, 4	4058·0	3	0, 0
4463·3	4	3, 6	3975·4	3	1, 0
4420·9	4	1, 4	3897·1	3	2, 0

SrO (*contd.*)

ULTRA-VIOLET SYSTEM

λ	I	v′, v″
3586·9	3	0, 1
3525·4	3	1, 1
3503·8	6	0, 0
3445·2	4	1, 0
3389·8	4	2, 0
3337·5	3	3, 0

INFRA-RED SYSTEM

Appearance. Degraded to the red.
Reference. K. Mahla, *Z.P.*, **81**, 625. (1933)†.

λ	v′, v″
8700·0	0, 3
8257·7	0, 2
7852·8	0, 1
7484·3	0, 0

Mahanti states that bands in the region 7000–5300 A, which appear when strontium salts are introduced into a flame, are due to Sr_2. Some observations, however, suggest that they are due to SrO.

TaO

Reference. C. C. Kiess and E. Z. Stowell, *Nat. Bur. Stand. J. Res.*, **12**, 459. (1934).
In studying the line spectrum of tantalum, as obtained from an arc between metallic poles, Kiess and Stowell record a band spectrum probably due to TaO. The bands are degraded to longer wave-lengths ; the following are the strongest bands :—

λ	I	λ	I	λ	I
5567·0	4	4679·5	3	4006·2	4
5385·2	3?	4651·9	3	3896·4	4
4901·6	3?	4154·4	7?	3747·2	4
4810·4	4	4092·1	3?	3625·7	4

Further bands were observed in the infra-red.

Te_2

MAIN SYSTEM

Occurrence. Absorption by tellurium vapour, fluorescence, and emission (presumably in discharge tubes).
Appearance. Degraded to the red. An extensive system consisting of a large number of bands.
References. B. Rosen, *Z.P.*, **43**, 69. (1927).
E. Olsson, *Z,P.*, **95**, 215. (1935).

The following measurements of the strong bands are by Olsson, with his vibrational quantum numbers. The intensities are from Rosen and are for absorption. The band heads are complex because of the isotope effect. Olsson's measurements are for the strongest head, $Te^{128}Te^{128} + Te^{130}Te^{126}$. Rosen's measurements are systematically lower than Olsson's by an amount increasing from zero at the red end

Te_2 (*contd.*)

of the system to 5 A at the violet end, this probably being largely due to the isotope effect.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4849·0	3	1, 7	4448·8	3	5, 2	4211·8	3	10, 0
4793·6	3	1, 6	4435·7	3	7, 3	4202·9	4	12, 1
4740·7	3	1, 5	4418·3	3	6, 2	4185·7	3	11, 0
4703·5	3	2, 5	4388·4	3	7, 2	4159·6	4	12, 0
4686·7	3	4, 6	4369·4	3	6, 1	4134·5	4	13, 0
4666·8	3	3, 5	4358·9	4	8, 2	4110·0	5	14, 0
4649·4	3	2, 4	4341·3	3	7, 1	4082·8	5	15, 0
4617·2	3	6, 6	4330·4	4	9, 2	4060·6	5	16, 0
4581·0	4	4, 4	4312·5	3	8, 1	4040·2	5	17, 0
4564·9	3	6, 5	4302·2	4	10, 2	4018·2	5	18, 0
4548·1	4	5, 4	4284·5	4	9, 1	3996·8	5	19, 0
4530·0	4	4, 3	4256·8	4	10, 1	3976·0	5	20, 0
4498·0	4	5, 3	4238·1	3	9, 0	3956·0	4	21, 0
4466·4	3	6, 3	4230·2	4	11, 1	3913·5	4	22, 0

OTHER SYSTEMS

References. M. Désirant and A. Minne, *C.R. Acad. Sci. Paris*, **202,** 1272. (1936).
Choong Shin-Piaw, *C.R. Acad. Sci. Paris*, **203,** 239. (1936) ; and *Ann. de Physique*, **10,** 173. (1938).

Désirant and Minne record bands in the visible in a high-frequency discharge, analysed into two systems with origins of the (0, 0) bands at $\nu = 18{,}900$ and 16,370.

Choong Shin-Piaw has studied the spectrum in the ultra-violet and gives a formula for bands in the region λλ2495–1975.

$TeBr_2$

Diffuse bands, degraded to the red, in the region λλ6500-5300 have been observed in absorption.

Reference. M. Wehrli, *Helvetica Phys. Acta*, **9,** 208. (1936)†.

Strongest bands :—

λ	I
6037	6
5957	7
5888	8
5816	9
5744	9
5676	8

$TeCl_2$

Diffuse bands, degraded to the red, in the region λλ6400–4725 have been observed in absorption.

Reference. M. Wehrli, *Helvetica Phys. Acta.*, **9,** 208. (1936) †.

Strongest bands :—

λ	I	λ	I
5758·6	3	5443·4	7
5720·0	2	5353·6	6
5656·1	3	5267·5	5
5634·3	3	5183·5	4
5536·4	5	5103	4

TeO

Occurrence. Discharge through tellurium vapour and oxygen in heated silica tube, and in absorption.

Appearance. Degraded to the red.

Reference. C. Shin-Piaw, *C.R. Acad. Sci. Paris,* **201,** 1181 (1935) ; and **202,** 127. (1936).

No measurements are available. The bands are in the region 3820–3190 A. The following formula is given :—

$$\nu = 29{,}499 + 372{\cdot}9\,(v' + \tfrac{1}{2}) - 5{\cdot}36\,(v' + \tfrac{1}{2})^2 - 796{\cdot}1\,(v'' + \tfrac{1}{2}) - 3{\cdot}40\,(v'' + \tfrac{1}{2})^2 \quad \mathrm{cm}^{-1}$$

TiCl

Occurrence. Discharge tubes (including high-frequency discharge) containing flowing titanium chloride, $TiCl_4$, vapour.

Appearance. Degraded to shorter wave-lengths. A strong close sequence with head at 4192 A.

Reference. K. R. More and A. H. Parker, *P.R.*, **52,** 1150. (1937).

In the following table all the observed heads of the (0, 0) band and the strongest (second) head of the other strong bands are given :—

λ	I	v′, v″
4199·5	1	0, 0
4192·7	10	0, 0
4189·1	4	0, 0
4188·0	8	0, 0
4184·5	6	0, 0
4181·8	5	0, 0
4183·1	9	1, 1
4172·2	9	2, 2
4160·3	6	3, 3
4106·9	3	1, 0

There are also weaker bands in the regions 4050–4000 A, 3935–3840 A, 3750–3720 A, but no measurements are available.

TiO

Three strong systems, in the red, the orange and the blue-green, have been attributed to this molecule.

Occurrence. In arcs and furnaces containing titanium dioxide and in discharge tubes containing titanium chloride and oxygen. The bands are a prominent feature of the spectra of M-type stars.

RED SYSTEM, γ

Appearance. Degraded to longer wave-lengths. The bands have rather widely-spaced triple heads, but the appearance is confused by overlapping.

Transition. A $^3\Sigma \rightarrow$ X $^3\Pi$, probably ground state.

Reference. F. Lowater, *Proc. Phys. Soc.*, **41,** 557. (1929)†.

The following are the strong heads as listed by Lowater. Intensities have been reduced to a scale of 10.

TiO (*contd.*)

λ	I	v′, v″	λ	I	v′, v″
7948·6	7	4, 5 Q_b	7197·7	7	1, 1 R_c, 2, 2 R_a
7907·3	5	4, 5 Q_a, 3, 4 R_c	7159·0	5	1, 1 R_b
7861·0	5	3, 4 R_b	7125·6	10	0, 0 R_c, 1, 1 R_a
7828·0	8	2, 3 R_c, 3, 4 Q_a	7087·9	9	0, 0 R_b
7820·1	7	3, 4 R_a	7054·5	7	0, 0 R_a
7705·2	7	1, 2 R_b	6852·3	5	4, 3 R_a
7672·1	8	0, 1 R_c, 1, 2 Q_a	6719·3	5	2, 1 R_a, 1, 0 Q_c
7666·4	5	1, 2 R_a	6714·4	5	1, 0 R_c
7628·1	7	0, 1 R_b	6681·1	5	1, 0 R_b
7589·6	7	0, 1 R_a	6651·5	4	1, 0 R_a
7269·0	5	2, 2 R_c, 3, 3 R_a	6215·2	5	6, 3 Q_c
7219·4	5	1, 1 Q_c			

ORANGE SYSTEM, β

Appearance. Degraded to the red. A single sequence of double-headed bands.

Transition. Uncertain. The appearance is suggestive of a singlet system, but efforts have been made to relate it to the $^3\Pi$ ground state.

Reference. F. Lowater, *Proc. Phys. Soc.*, **41**, 557. (1929)†.

The following are the strongest heads :—

λ	I	v′, v″
5694·4	3	3, 3 R
5661·6	6	2, 2 R
5629·3	6	1, 1 R
5603·8	3	0, 0 Q
5597·8	7	0, 0 R

TlBr

Occurrence. In absorption by thallium bromide vapour.

Appearance. Degraded to the red.

Reference. K. Butkow, *Z.P.*, **58**, 232. (1929)†.

Strongest bands (for isotope $TlBr^{79}$) :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3556·5	3	1, 6	3486·4	7	1, 3	3440·9	6	1, 1
3532·9	4	1, 5	3475·3	8	0, 2	3429·6	10	0, 0
3509·7	5	1, 4	3463·6	8	1, 2	3418·2	9	1, 0
3498·4	5	0, 3	3452·4	9	0, 1	3408·2	6	2, 0

TlCl

Absorption bands observed in thallium chloride vapour. Bands λλ3392–3176, degraded to the red. They have also been observed in absorption, as impurities, in other substances, especially cadmium.

Reference. K. Butkow, *Z.P.*, **58**, 232. (1929)†.

Strong bands :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3323·4	6	5, 3	3263·6	8	3, 3	3230·8	9	2, 4
3300·1	6	4, 2	3260·1	6	3, 4	3221·1	10	0, 0
3289·8	6	4, 4	3251·5	8	2, 1	3193·2	7	0, 1
3281·3	6	3, 1	3240·6	8	2, 2	3182·6	6	0, 2
3270·2	7	3, 2	3234·4	7	2, 3			

TlF

Three systems observed in absorption by thallium fluoride vapour, and two in emission.

Reference. H. G. Howell, *P.R.S.*, **160**, 242. (1937)†.

SYSTEM $^3 1 \rightarrow {}^1\Sigma$, GROUND STATE

Most bands degraded to shorter wave-lengths, but some to red.

(1, 1) 2848·0, (0, 0) 2843·5, and (1, 0) 2810·6 A.

SYSTEM $^3 0 \rightarrow {}^1\Sigma$, GROUND STATE

Degraded to red.

(0, 1) 2748·1, (2, 2) 2737·1, (1, 1) 2724·9, and (0, 0) 2713·6 A.

SYSTEM $^1\Pi \leftarrow {}^1\Sigma$, GROUND STATE

In absorption only. (0, 0) band at 2198·0 A.

TlH

Several band systems were observed by Grundström and Valberg when thallium metal was heated with hydrogen in a furnace and when an arc between thallium and copper poles was run in hydrogen at about 500 mm. pressure. The bands are not yet completely systematised.

Reference. B. Grundström and P. Valberg, *Z.P.*, **108**, 326. (1938)†.

B→A SYSTEM

v′, v″	Origins	Heads
0, 0	5706·2	none
0, 1	6180·9	none

C→A SYSTEM. Degraded Red.

v′, v″	Origins	R Heads
0, 1	5903·8	5895·2
1, 2	5914·4	5911·7
0, 2	6394·7	6382·9
0, 3	6952·8	6935·9

D→A SYSTEM. Degraded Red.

v′, v″	Origins	R Heads
0, 1	5742·7	5739·2
1, 2	5772·3	—
0, 2	6206	—
1, 3	6223·2	6220·2
0, 3	6730·6	6725·0
1, 4	6729	—
0, 4	7327	7320

E→A SYSTEM. Degraded Red.

v′, v″	Origins	R Heads
0, 2	6058·6	6055·2
1, 3	6062·4	—
0, 3	6557·4	6553·2

TlI

Occurrence. In absorption by thallium iodide vapour.

Appearance. Diffuse headless bands.

TlI (*contd.*)

Reference. K. Butkow, *Z.P.*, **58**, 232. (1929)†.

The following are the bands as listed by Butkow. No intensities are available, but from the reproduction it appears that the shorter wave-length bands are the stronger.

λλ3808, 3836, 3896, 3933, 3967, 4000, 4030, 4062, 4092, 4120, 4152, 4181 and 4211.

VO

Occurrence. In the flame surrounding arc containing vanadium metal or oxide.
Appearance. Degraded to red. Double-headed, separation between R and Q heads about 0·8 A.
Transition. Probably $^2\Delta \rightarrow {}^2\Delta$.
Reference. P. C. Mahanti, *Proc. Phys. Soc.*, **47**, 433. (1935)†.

R heads of strong bands :—

λ	I	v′, v″
6532·8	6	1, 3
6477·8	6	0, 2
6086·4	8	0, 1
5736·7	10	0, 0
5517·3	5	2, 1
5469·3	9	1, 0

WO

Occurrence. High-tension arc between tungsten electrodes in air.
Appearance. A complex system of single-headed bands degraded to the red.

The following are rough measurements by Foster and Gaydon of the strong heads. The system has not been analysed and is attributed to WO on experimental evidence only.

λ	I	λ	I	λ	I
5396	3	4709·4	10	4414	5
5338	3	4609	8	4395	4
5210	5	4590·5	8	4338·5	5
4932	3	4562	4	4313	4
4903	3	4523	5	4284	4
4824	6	4473·5	5	4271·0	4
4806	9	4460	5	4110·5	2

YO

Occurrence. In arc containing yttrium salts.
References. L. W. Johnson and R. C. Johnson, *P.R.S.*, **133**, 207. (1931).
W. F. Meggers and J. A. Wheeler, *Bur. Stand. J. Res.*, **6**, 239. (1931)†.

Orange System

Appearance. Degraded to the red. Long sequences.
Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.

The following measurements of the strong heads at the beginnings of the main sequences are from Johnson and Johnson :—

YO (*contd.*)

λ	I	v′, v″	λ	I	v′, v″
5697·8	5	1, 0 i Q	5939·1	8	0, 0 i R
5713·9	6	2, 1 i Q	5956·4	7	1, 1 i R
5730·2	7	3, 2 i Q	5972·2	10	0, 0 i Q
5747·0	8	4, 3 i Q	5987·7	10	1, 1 i Q
5764·3	7	5, 4 i Q	6003·6	10	2, 2 i Q
5842·0	4	1, 0 ii Q	6096·8	8	0, 0 ii R
5858·9	5	2, 1 ii Q	6114·8	7	1, 1 ii R
5876·2	4	3, 2 ii Q	6132·1	10	0, 0 ii Q
5912·3	6	5, 4 ii Q	6148·4	10	1, 1 ii Q
5931·1	5	6, 5 ii Q	6165·1	10	2, 2 ii Q

Blue-Green System

Appearance. Degraded to the red. Close double-headed bands, separation about 0·8 A.

Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

The following measurements of the first heads of the strong bands are by Johnson and Johnson :—

λ	I	v′, v″
5077·9	4	2, 3
5049·7	5	1, 2
5024·2	6	0, 1
4841·9	7	1, 1
4817·4	10	0, 0
4649·2	9	1, 0

Zn_2

References. H. Hamada, *Phil. Mag.*, **12**, 50. (1931)†.
J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).

Hamada has studied the emission by zinc in a hollow cathode. The zinc lines, especially λλ2139 and 3076 are broadened and show patches of continua and flutings attributed to incipient formation of Zn_2 molecules.

Walter and Barratt observe a diffuse band in absorption at about 3050 A.

ZnBr

Bands between 3113 and 3027 A. have been observed in absorption. They are degraded towards the red.

Reference. J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).

Strongest heads :—

λ	I
3110	4
3102	2
3071	4
3068	3
3064	2

ZnCl

References. J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).
S. D. Cornell, *P.R.*, **54**, 341. (1938).

ZnCl (*contd.*)

$\lambda\lambda$2993–2903 System

Occurrence. Observed by Cornell in a high-frequency discharge, and by Walter and Barratt in absorption.

Cornell apparently observed strong sequences (degraded to longer wave-lengths) at $\lambda\lambda$2976·2 and 2942·6 and a weaker sequence at λ2910·0.

The following are the strongest absorption bands (intensities in brackets): $\lambda\lambda$2956 (8), 2943 (5), 2934 (10), 2923 (5) and 2911 (2).

λ2074·4

A single sequence of bands degraded to the red observed by Cornell in a high-frequency discharge.

ZnH

Reference. G. Stenvinkel, *Dissertation*, Stockholm. (1936).

4300 A. System $^2\Pi \rightarrow {}^2\Sigma$, Ground State

Bands with P and Q heads degraded to the violet, obtained with zinc arc in hydrogen at reduced pressure and in quartz discharge tube containing zinc vapour and hydrogen. See Plate 4.

v′, v″	$^2\Pi_{\frac{1}{2}} \rightarrow {}^2\Sigma$ Origins	Heads (I) Q	P	v′, v″	$^2\Pi_{\frac{3}{2}} \rightarrow {}^2\Sigma$ Origins	Heads (I) Q	P
0, 3	5223·0			0, 3	5131·5		
0, 2	4905·3			0, 2	4824·5		
0, 1	4578·6			0, 1	4523·9		
0, 0	4299·1	4301 (10)	4260 (8)	0, 0	4237·0	4240 (10)	4326 (5)
1, 1	4238·3			1, 1	4178·2		
1, 0	3985·6	3989 (3)		1, 0	3932·2	3935 (3)	
2, 0	3726·0			2, 0	3679·4		

Ultra-violet System $^2\Sigma \rightarrow {}^2\Sigma$, Ground State

An extensive system of bands degraded to the red.

Origins

v′ v″	λ	v′, v″	λ
0, 5	4703·1	4, 0	3219·3
0, 4	4520·0	5, 0	3132·7
0, 3	4310·9	6, 0	3054·1
1, 2	3934·0	7, 0	2981·8
1, 1	3731·7	8, 0	2916·1
2, 0	3418·3	9, 0	2855·7
3, 0	3314·3	10, 0	2800·7

ZnH⁺

Reference. E. Bengtsson and B. Grundström, *Z.P.*, **57**, 1. (1929).

2152 A. System, $^1\Sigma \rightarrow {}^1\Sigma$

An extensive system of singlet bands degraded to the red. The system is obtained in zinc arc in hydrogen at low pressures.

ZnH+ (*contd.*)

v′, v″	R Heads
1, 0	2091·7
2, 1	2115·1
0, 0	2151·9
0, 1	2240·2
1, 2	2261·5
0, 2	2332·0
1, 3	2350·7
2, 4	2366·5

ZnI

Bands λλ3393–3258 have been observed in discharge tube containing ZnI_2; they are degraded to shorter wave-lengths.

Reference. K. Wieland, *Helvetica Phys. Acta.*, **2,** 42. (1929).

Heads of strongest sequences :—

λ	I	Sequence
3367·3	5	0, 2
3342·6	8	0, 1
3318·0	10	0, 0
3291·1	7	1, 0

ZnI_2

A continuum 6400–3500 A. and a system of bands λλ2450–2250 degraded to the red have been observed by Wieland (see under ZnI above) in a discharge tube containing ZnI_2.

ZnS

Reference. P. K. Sen Gupta, *P.R.S.*, **143,** 438. (1933–4).

Continuous absorption from 2800 A. to shorter wave-lengths with maximum around 2300 A.

ZrO

Occurrence. Zirconium oxide in arc.

Appearance. Degraded to the red. Three overlapping systems and a few unclassified bands.

References. F. Lowater, *Proc. Phys. Soc.*, **44,** 51. (1932)†.
F. Lowater, *Phil. Trans. Roy. Soc.*, **234A,** 355. (1935)†.

The following are the wave-lengths of the strongest heads of the three systems and the unclassified bands as listed by Lowater. The intensities have been reduced to a scale of 10.

α System, Blue

Transition. C $^3\Pi \rightarrow$ X $^3\Pi$, ground state.

λ	I	v′, v″	λ	I	v′, v″
4850·1	3	0, 1 R_1	4521·3	3	3, 2 R_1
4847·2	3	0, 1 R_2	4519·3	3	3, 2 R_2
4827·5	4	0, 1 R_3	4496·2	4	2, 1 R_1
4644·7	5	1, 1 R_3	4493·8	4	2, 1 R_2
4640·6	10	0, 0 R_1	4471·5	5	1, 0 R_1
4637·9	9	0, 0 R_2	4469·5	4	1, 0 R_2
4619·8	8	0, 0 R_3			

ZrO (*contd.*)

β SYSTEM, YELLOW

Transition. B $\rightarrow$ X $^3\Pi$, ground state.

λ	I	v′, v″	λ	I	v′, v″
6070·0	3	1, 2 R_3	5629·0	6	0, 0 R_2
5809·2	4	3, 3 R_3	5551·7	5	0, 0 R_1
5778·5	5	2, 2 R_3	5545·2	3	4, 3 R_3
5748·1	8	1, 1 R_3	5515·3	3	3, 2 R_3
5724·0	6	0, 0 Q_3	5491·7	3	5, 4 R_2
5718·1	10	0, 0 R_3	5485·7	3	2, 1 R_3
5658·1	5	1, 1 R_2	5456·5	4	1, 0 R_3

γ SYSTEM, RED

Transition. A $^3\Sigma$ $\rightarrow$ X $^3\Pi$, ground state.

λ	I	v′, v″	λ	I	v′, v″
6996·3	3	3, 4 R_3	6324·3	3	3, 3 R_1
6959·9	3	2, 3 R_3	6292·8	7	2, 2 R_1
6543·0	5	2, 2 R_3	6260·9	8	1, 1 R_1
6508·1	9	1, 1 R_3	6229·4	9	0, 0 R_1
6473·7	10	0, 0 R_3	6021·3	3	1, 0 R_2
6412·3	6	2, 2 R_2	5977·7	3	3, 2 R_1
6378·3	8	1, 1 R_2	5439·4	4	5, 2 R_1
6344·9	9	0, 0 R_2			

UNCLASSIFIED BANDS

λ	I	λ	I	λ	I
6153·9	4	5553·1	5	4534·4	4
5908·5	5	5539·3	3	3682·4	3
5860·1	6	5436·9	4	3492·0	3
5610·0	5	5185·0	7		

PRACTICAL HINTS

The following section contains a few brief notes on various minor points which arise in the identification of molecular spectra, and which have been found to trouble the inexperienced, but which are not usually dealt with in the general textbooks.

On the Identification of Bands. It should be borne in mind that the most satisfactory comparison of two spectra is made by bringing plates or prints together, side by side. It is preferable that the spectra should be taken with the same instrument in the same state of adjustment, but if this is not possible, enlargements from the plates may be made to the same scale by means of the iron arc comparison spectra. That such direct comparison is not always necessary is of course true ; in fact, the object of constructing these tables is largely to make this unnecessary ; nevertheless, there will remain cases where resort must be had to this method. This is especially true in dealing with sources of very low intensity, such as phosphorescent glows, fluorescence, the night sky, comet tails, etc., where, in order to get a record in a reasonable time, instruments of small dispersion are used with wide slits. In such cases, while the wave-lengths recorded by the observer are not infrequently useless for identification, much may be done with his published photograph. Direct comparison is also useful in dealing with spectra which consist of small regions of continuum, headless bands or other structures lacking outstanding features capable of accurate measurement, and in dealing with spectra which contain several band systems superimposed. Small differences in complicated spectra, otherwise the same, and points of resemblance in spectra mainly different are certainly most readily detected by direct comparison.

Where the dispersion is sufficient to allow of reasonably accurate measurements on well-defined heads, identification by means of wave-lengths becomes practicable. In using these tables the following procedure is suggested as a guide :—

(1) Select two or three of the strongest bands of the spectrum to be identified and compare their wave-lengths with the list of persistent bands. If entries are found in close agreement with these wave-lengths, and if the bands are degraded in the appropriate direction, refer to the detailed list for the corresponding system.

(2) If all of the bands given in the detailed list are found to be present in the spectrum and the details of appearance and occurrence are applicable, the identity may be considered to be established. The approximate agreement of a few of the bands should not be accepted as identification unless the selection can be reasonably explained, *e.g.*, in absorption it may happen that only those bands with $v'' = 0$ are obtained or in fluorescence only those arising from certain values of v' ; a random selection should be rejected. If bands remain unaccounted for in the spectrum they may be an extension of the system, if they are the same type of band, or they may belong to another system of the same molecule. If bands are still outstanding after these possibilities have been examined, select the strongest of them and refer again to the list of persistent bands.

(3) Having identified as many systems as possible by this method, it is usually worth while to refer to the detailed lists for systems of other molecules which may be

formed from the elements now known to be present. In this way weak bands which have escaped notice in a crowded spectrum are often detected and accounted for.

(4) Determine the origin of strong atomic lines if any are present. This may provide a clue to an identification, support one already made, or supply the clearest evidence of an unsuspected impurity.

(5) Consider whether the systems obtained are likely to occur in the given source. Such considerations often help to eliminate erroneous identifications due to chance coincidences.

Sources. It is desirable to have some acquaintance with the properties of various sources commonly employed for the production of spectra, both in regard to choosing a source suitable for the production of a given spectrum, and also in regard to assessing the probability of a suspected system appearing in the given source.

The evaluation of the absolute intensities of the band systems of a molecule in different sources requires a knowledge of such quantities as the concentrations of the various atoms and molecules present, the proportion of each in their possible states of excitation and ionisation, with their velocity distributions, as well as the concentration and velocity distribution of electrons, and, in addition, a knowledge of the collision processes which may occur. Such knowledge is not in general available, but fortunately it is possible to make a few generalisations of some value as a result of direct observation, without going into so much detail.

Flames. Many band systems are observed in flames ; some by the direct combustion of inflammable substances ; others by the introduction of additional substances into a flame already established. The general characteristic of the band systems obtained in this way is that they arise from transitions between a few of the lowest levels of the molecule concerned. The energy of the upper level involved rarely exceeds 5 e-volts, while the lower level is in most cases the ground state. Without exception, flame bands have been found to belong to molecules which are electrically neutral, but very frequently the molecules are not stable in the chemical sense, thus such combinations as CH, NH and OH are of very common occurrence. A few examples will serve to illustrate these points. The 4300 A. and 3900 A. bands of CH, the 3064 band of OH and the Swan bands of C_2 appear readily enough in the flames of hydrocarbons, but the Third Positive and the Angstrom bands of CO, which require more than 10 electron volts for their excitation, are absent. Different systems occur most strongly in different parts of the flame ; the OH and CH bands are spread through the blue part of a Bunsen burner flame using coal-gas, but the Swan bands are restricted to the green part of the roaring flame, which in fact owes its colour mainly to the presence of these bands. The 3360 A. band of NH, the 3064 A. band of OH and the red and violet systems of CN are given by a flame of moist cyanogen. The 3360 A. band of NH is also obtained strongly from the oxy-ammonia flame, but the systems arising from more excited levels, which are known from other sources, do not appear as well. This is also true of the cyanogen flame. To obtain other systems by the introduction of additional substances, it is necessary that these should be brought to the gaseous state within the flame. Gases and vapours may be mixed directly with the gas being burnt ; volatile liquids may be sprayed into the flame and volatile solids introduced on suitable supports. The number of spectra which may be obtained in this way is thus restricted by the necessity of finding suitable volatile substances to add to the flame. This restriction is not so far reaching as it appears at first sight, since the substance whose spectrum is required does not have to be introduced directly, but may be formed as a result of chemical reaction within the flame. Thus in the

example mentioned above, although carbon is among the least volatile of all substances, yet the bands of C_2 are readily observed during the combustion of hydrocarbons, even being observed in a candle flame. Again, in cases where the metallic oxides are refractory, the spectra of the oxides may be obtained by introducing the metal itself or, more generally, by introducing a volatile halide. Chemical action in the flame also allows the spectra of many metal hydrides to be obtained from flames in cases where the metal does not form a stable compound with hydrogen. Thus the spectra of MgH and CuH may be obtained by putting the finely divided metal into a hydrogen flame and that of NiH by allowing the vapour of nickel carbonyl to mix with the hydrogen. In the examples quoted so far the band systems obtained from flames are readily obtained in other ways, from the electric arc or the discharge tube for the most part, but there are a few systems known which appear readily in the flame yet are not obtained or are only obtained with difficulty in other sources. Such are the CO-flame bands, the ethylene-flame bands and the α-bands of ammonia. It is unlikely that such systems arise from highly excited states of the molecules concerned ; it appears more probable that the equilibrium configurations for the excited states differ considerably from those for the normal state. According to the Franck-Condon theory excitation by the absorption of light or by electron impact takes place in such a way that the instantaneous kinetic energy and configuration of the nuclei are unchanged during the change of electronic state ; therefore in absorption or in sources where excitation is mainly by electron impact, band systems arising from states in which the configuration of the nuclei differs markedly from that of the normal state may be expected to be weak. In the flame, where excitation occurs mainly as a result of collisions between atoms and molecules, these systems may be relatively strong.

The Arc. In general, arcs develop higher temperatures than flames and therefore are able to volatilise many substances which resist flames. The arc spectra of atoms contain many more lines than the flame spectra, for there is usually sufficient energy available in collision processes in the arc to excite all states up to ionisation, and, in the case of readily ionised elements like calcium, even to excite a few states of the ion. With molecules the behaviour is similar ; in the arc spectrum more band systems appear than in the flame spectrum as higher levels are excited. The number of additional systems is not usually great, however, for just as in atomic series the number of lines distinguished is limited by the pressure, so other factors, including pressure, limit the number of band systems. The arc in air has been widely used for the production of the spectra of oxides and halides of the metals ; in some cases, such as CuCl and TiO, the bands are more clearly shown in the flame of the arc than in the core. By enclosing the arc it may be run in various gases and at various pressures ranging from a few millimetres of Hg to several atmospheres. The spectra of many of the metallic hydrides have been obtained using arcs in hydrogen at a pressure of a few centimetres of mercury. Reduction of the pressure favours ionisation ; thus the spectra of Mg^+ and MgH^+ can be obtained easily from an arc between poles of magnesium in an atmosphere of hydrogen by reducing the pressure to a few millimetres of Hg. Increase of pressure up to several atmospheres is sometimes successful in producing band systems not otherwise obtained, such as those of SnH and PbH. This occurs where states of the molecule are subject to predissociation. Band spectra emitted by arcs do not necessarily arise from molecules containing the material of the poles, sometimes only the atmosphere is involved ; many arcs produce the OH bands if water vapour is present, and several, notably the Cu arc, produce the NO γ-bands in air. Under reduced pressure such bands as those of PN, NH 3360 A. and the Second

Positive system of nitrogen are produced when the appropriate elements are present in the atmosphere.

Discharge Tubes. Although as sources of illumination flames and open arcs have the advantage of simplicity, discharge tubes offer greater scope for the variation of conditions. The discharge tubes formerly used were of low intensity but many of the types now in use compare favourably with the arc in this respect. Moreover, discharge tubes have the additional advantage of steadiness, so that continual readjustment of the image of the source on to the slit is avoided. In what is called the normal discharge seven different regions have been distinguished, viz. : (1) the anode glow, (2) the positive column, (3) the Faraday dark space, (4) the negative glow, (5) the cathode dark space, (6) the cathode glow and (7) the primary dark space. The most luminous parts and therefore those most used in spectroscopic work are the positive column and the negative glow.

The Positive Column. With an uncondensed discharge the positive column presents a source which resembles the arc in many ways. The spectra obtained from it are usually those of uncharged atoms and molecules but the number of excited states reached is greater than in the flame or the arc in air. Thus with CO or CO_2 present the Fourth Positive and Angstrom bands of CO appear readily in the positive column although they are not observed in the CO flame and only with difficulty in the arc. Excitation appears to be due mainly to electron impacts, the electrons having a velocity distribution of the Maxwell-Boltzmann type but for a temperature much higher than that of the gas molecules in the tube. The actual distribution depends very much on the nature and pressure of the gas in the tube and on the intensity of the electric field along the column. Both lowering the pressure and increasing the intensity of the field tend to favour higher stages of excitation ; the variation takes place in such a way that the state of excitation appears to depend mainly on the ratio of the field to the pressure, X/p, or perhaps rather more accurately on $X.\lambda$, the product of the field and the mean free path of the electron.

The Negative Glow. In the region of the negative glow there accumulates a considerable positive space-charge. The ions are excited to emission by electrons from the direction of the cathode and as a result the negative glow gives largely the spectra of positively charged ions. A modification of the form of the cathode, known as the hollow cathode, allows fuller advantage to be taken of this peculiarity of the negative glow. The cathode takes the form of a hollow cylinder or a massive block through which a slot has been cut. For a certain range of pressure the negative glow passes into the recess, becoming at the same time more brilliant. For the production of molecular spectra the linear dimensions of the recess are usually greater than for the types of hollow cathode used for the production of fine lines for the study of hyperfine structure.

The Addition of Other Gases. Several molecules are known to emit somewhat different spectra in the presence of different gases. Thus, in the presence of excess of one of the rare gases, CO is found to give the Cameron bands and the Triplet bands. Again, whereas the positive column in pure nitrogen appears of an orange colour, the addition of oxygen causes the colour to change to pink, due to a weakening of the red and yellow bands of the First Positive system of N_2 relative to the blue and violet bands of the Second Positive system. The mechanism in most cases is still somewhat obscure. The following, however, are processes which may be expected to occur. If the excess is an inactive gas, such as one of the rare gases, then excited molecules which ordinarily lose their energy in a collision with their fellows may collide with rare gas

molecules without loss of energy. There is then greater probability of the molecule radiating band systems arising from these particular excited states. This is especially likely to be true for metastable states of the molecule. On the other hand, if there are metastable states of the molecules of the added gas which are excited, these may in a collision, hand over their energy to the other molecules, thereby exciting states of these molecules which are not readily excited by electron impact. Also, there is the possibility that the excess of other gas may so modify the velocity distribution of the electrons as to cause a marked change in the relative numbers of molecules excited to different levels.

Controlled Electron Sources. The variation of intensity of the various band systems of a molecule with the velocity of impacting electrons can be studied more accurately in discharge tubes where the velocity can be adjusted as desired. Such tubes usually consist of a heated wire as a source of thermionic electrons, and a grid separated from it by a distance less than the mean free path of an electron at the pressure at which the tube is to be used. By varying the voltage across the grid and filament, the velocity of the electrons can be gradually increased until light is emitted from the gas in the tube. This indicates that molecules of the gas are being raised to an excited state ; as the voltage is still further increased other excited states are reached with the consequent emission of other band systems.

High Frequency Discharges. Two kinds of high-frequency discharge are used fairly extensively in spectroscopic work. They are often spoken of as the ring discharge and the valve oscillator discharge respectively. In the ring discharge a condensed spark is used to set up damped oscillations in a circuit containing suitable inductance and capacity. The inductance consists of a coil of a few turns wound around a spherical or cylindrical vessel containing gas or vapour at low pressure. Under these conditions the gas or vapour may be made to glow brilliantly, the spectra emitted depending on the violence of the discharge, which may be controlled by varying the length of the spark gap. As the violence is increased, the spectrum may be made to change from bands due to molecules to lines due to atoms which have lost several electrons. Decrease of pressure favours greater excitation as with other forms of discharge. In the valve oscillator discharge, a thermionic valve is used to maintain continuous high frequency oscillations in a tuned circuit. A tube containing gas at low pressure may be made to emit radiation by connecting the oscillating circuit to electrodes of the usual type, to external electrodes consisting of foil wrapped around the outside of the tube or to a wire coiled about the tube in the form of an inductance as with the ring discharge. The valve oscillator as generally used with a plate voltage of 1,000–2,000 volts gives spectra which resemble those of the positive column at higher pressures but tend to change to those of the negative glow as the pressure is reduced. High frequency discharges provide a useful means of exciting afterglows and have the advantage that contamination with material from electrodes can be avoided.

Active Nitrogen. The ring discharge or condensed discharge through carefully purified nitrogen are both capable of giving rise to a strong orange-coloured afterglow. The spectrum of this afterglow consists of some of the bands of the First Positive system of N_2. If a small amount of oxygen is mixed with the nitrogen some of the bands of the β-system of NO also appear ; in fact, this system is best obtained in this way. In the positive column of a discharge tube the γ-system is much stronger than the β-system whereas in the afterglow the reverse is the case. The equilibrium constants for the upper state of the γ-system are much closer to those of the normal state than are those for the upper state of the β-system. Many other band systems can be

excited by introducing appropriate gases or vapours into nitrogen thus activated, the excitation often being accompanied by chemical reaction. Thus organic compounds such as CCl_4 and C_2H_2 yield systems of CN, CH, C_2, and sometimes NH; $SiCl_4$ yields SiN systems; and, with a trace of oxygen, BCl_3 yields systems of BO. It is usually difficult to remove all trace of oxygen, so that band systems of the oxides often occur quite strongly when other compounds, such as the halides of metals, are added to active nitrogen. A band system produced in active nitrogen often differs considerably in appearance from the same system as observed in the arc or discharge tube; the violet CN bands form a good example. The bands produced in active nitrogen have much shorter branches than in the arc but many more bands of the system are observed; fewer states of rotation are excited, but more of vibration.

The Spark. The condensed spark discharge is not much used for the production of molecular spectra, since the violence of the discharge is such that many lines of atoms in various stages of ionization are produced, but few band systems. Sometimes, however, band systems are emitted in an afterglow following the passage of the spark and may be photographed if a synchronized shutter is adjusted to cut off the light of the spark itself from the spectrograph while exposing it to the afterglow. The uncondensed discharge is used in a variety of ways. The discharge from a high tension transformer between metal rods in air is useful for the production of the spectra of some metallic oxides, the bands being obtained with fewer atomic lines and with shorter branches than in the arc; this facilitates vibrational analysis. By enclosing the discharge it may be used to excite the spectra of various gases and vapours. The uncondensed discharge has also been used in conjunction with flames, in some cases to increase the intensity of bands emitted by the flame itself, and in other cases to introduce the vapour of metals of high melting point into the flame for the production of the spectra of their oxides or hydrides. The spectra of the hydrides of nickel, manganese and chromium have been produced in this way by passing the discharge between poles of the appropriate metal in a flame of hydrogen.

Absorption. It is frequently convenient to observe band systems in absorption and this is particularly true where polyatomic molecules are concerned, for these are usually decomposed in emission sources. Observed in absorption a molecular spectrum differs in some respects from one taken in emission. Unless the temperature is unusually high, absorption only occurs for those systems which have the normal state of the molecule as lower level, and only for those bands of these systems which start from the first two or three vibrational levels of the normal state. Thus the absorption spectrum is in general much more simple than the corresponding emission spectrum. If the nuclear configuration for the equilibrium position of the upper state of a system is very different from that for the lower state it may happen that the absorption spectrum shows few if any bands in common with the emission spectrum. In absorption, transitions take place from a few of the lowest vibrational levels of the lower electronic state to high vibrational levels of the upper electronic state, while in emission, transitions take place from a few of the lowest vibrational levels of the upper state to high vibrational levels of the lower state. Since the spacing of the vibrational levels is different for the two electronic states it is sometimes difficult to recognize that the bands belong to the same system. This applies particularly to polyatomic molecules.

It is sometimes desired to establish proof of the presence of a molecule, especially if this is a radical not stable chemically, by attempting to observe its spectrum in absorption. Sufficient consideration is not, however, always given to the conditions

which must be fulfilled for this observation to be possible. The individual lines of band structure are usually very sharp and will only be observed in absorption if the power of resolution of the spectrograph is comparable with the width of the lines themselves. This usually means that an instrument of high dispersion must be used and the slit kept as narrow as possible. This point is well illustrated by observing how the number of Fraunhofer lines which can be distinguished in the solar spectrum depends on the resolving power of the spectrograph used and on the width of the slit. Since the width of an absorption line depends on the number of absorbing molecules in the line of sight, an increase of the length of absorbing column improves the chance of observing the line, but often, as in dealing with flames and explosions, such increase is limited. Lines crowded together to form heads resemble wide lines and as such may be observed with smaller resolution than is necessary to show the individual lines. It often happens therefore that the head of a band may be observed in absorption but not the open branches which accompany it when it is observed in emission with the same spectrograph.

Collimation. Beginners are sometimes troubled by unduly long exposures, lack of definition, doubling and shading of the lines, these defects arising from poor collimation. Whenever a spectrograph is used, care should be taken to see that it is collimated so that it is used to the best advantage ; and this includes the giving of due consideration to the selection and adjustment of optical parts, such as condensing lenses, placed between the source and the slit. Assuming that the optical parts of the spectrograph are without fault, it is essential, to obtain speed and good definition, that the dispersing system, prism or grating, should be uniformly filled with light. At the same time, it is undesirable that additional light should be admitted to the spectrograph through the slit as this extra light, which does not pass through the optical system, is merely scattered within the instrument causing a background of fog on the plate. The ideal is therefore that the light entering the slit should diverge from it in the form of a cone with its axis along the optical axis of the collimator and its base just filling the optical system. If the source is sufficiently extended, it may be brought near enough to the slit for this condition to be fulfilled ; if it is not, a condensing lens must be used. In either case, the first adjustment is to arrange the source so that it is on the axis of the collimator. A simple procedure for making this adjustment is as follows : The slit of the spectrograph is opened to about 1 mm. and the source moved (the standard iron arc is convenient for this purpose) both laterally and vertically until the narrow pencil of light entering the slit falls on the centre of the prism or grating of the spectrograph. If a condensing lens is to be used it is next put in place so as to focus an image of the source on the slit. It is an advantage to use the enlarged rather than the diminished image on the slit, provided care is taken to ensure that the full aperture of the spectrograph is used. Use of the diminished image does not give an increase of speed proportional to the brightness of the image, since the light is spread over a cone of larger solid angle, thus more than filling the optical system and flooding the spectrograph with light. The diminished image also has the additional disadvantage of giving a very narrow and uneven spectrum. When the source and lens have been set in position the adjustment should be checked by placing the eye in the plane of the spectrum and observing whether the optical system is completely and uniformly filled with light. When collimating it is often useful to remember that light travelling in the opposite direction takes the same path through an optical system. Thus with large concave gratings, where the grating and source rooms are separate, it is convenient to place a small strip of white paper in front of the grating, illuminate it so that it may be

seen through the slit from the source room, and then to place the arc (with current off) in line with the paper and the slit. The lens may then be arranged to focus the image of the arc on the slit. Again, if a source is difficult to move when running it may be set in position, once the lens has been fixed, by illuminating the slit, finding the real image of the slit, and then adjusting the source to coincide with this image. In the majority of experiments a condensing lens is used. Once the lens has been adjusted to be on the axis of the instrument it may be kept there and the source changed as required, the source automatically coming on to the axis when its image is focused on the slit. If the work is sufficiently routine, it may be worth while to arrange an optical bench in conjunction with the spectrograph. Concave mirrors may also be used to focus the source on to the slit and have the advantage that the image is achromatic. Mirrors, however, are otherwise inconvenient and lenses are generally preferred. It must be remembered, when using a lens, that the different wave-lengths come to a focus at different distances from the lens. With large instruments, when only a small region of the spectrum is being photographed at a time, this is not serious if care is taken to focus for the wave-length region required but with small instruments covering a large range, such as the usual quartz spectrographs, it may lead to great variations of intensity. If a particular region is required the lens may be adjusted to bring this to a focus but if the whole range is required, as in exploratory work, it is usually of advantage to focus the farthest ultra-violet image on the slit. This may be done by using a fluorescent screen in front of the slit and a source, such as the copper arc, which is rich in lines about 2100 A. to adjust the lens. In this way a very uniform intensity may be obtained from the visible to the far ultra-violet.

Comparison Spectra. To obtain the wave-lengths of features of a spectrum, a comparison spectrum is photographed alongside. The comparison most generally used is the iron arc. The spectrum of the iron arc contains a very large number of sharp strong lines distributed fairly evenly from about 2330 A. to the infra-red region ; there are one or two gaps and the orange region is somewhat confused by bands of FeO, but on the whole it is good throughout the visible and near ultra-violet regions. The lines have been investigated by the International Astronomical Union and accurate standard values of their wave-lengths set up. To obtain the highest accuracy the form of arc lamp used to produce the spectrum has been standardised following the recommendations of Pfund. The electrodes are vertical ; the anode below, consisting of a bead of iron oxide supported on a massive rod of iron, and the cathode above, consisting of a rod of iron 6–7 mm. in diameter, having a massive cooling cylinder of copper or iron close to the end of the rod. The arc is operated on a 110–250 volts supply with a current of 5 amperes or less. For accurate measurements the arc should be 12–15 mm. long and light should be taken only from the central zone at right angles to the axis of the arc not exceeding 1·5 mm. in width.

For the region 2000–2300 A. the copper arc is employed. Since the spectrum of the copper arc is relatively simple it is sometimes used as a general comparison spectrum for work with small dispersion. The practice is not, however, much to be recommended as the appearance of the spectrum is rather variable, there are few lines at the red end of the spectrum, and bands of NO often confuse the ultra-violet region.

Mercury shows far too few lines to be of much use as a comparison spectrum, but the frequent employment of the mercury arc as a source for fluorescence and photochemistry has led to its adoption for this purpose. The principal features of the spectrum are of course very easily recognised.

For the yellow and red regions a neon spectrum has been recommended. A neon

discharge tube is a very convenient source but unfortunately the lines are rather far apart for use with high dispersion and the useful range is very limited.

Reproductions of the spectra of iron, copper, mercury and neon are shown in Plates 7 and 8.

Measurement. If a spectrum is to be measured the comparison spectrum should be photographed alongside, so that there is a slight overlap. In doing this the adjustments of the spectrograph, the plate holder and the dark slide should not be disturbed between the two exposures ; the spectra are brought into the desired positions by use of a Hartmann diaphragm in front of the slit for a prism instrument, and by use of a Rowland shutter in front of the plate for a grating instrument.

To obtain the wave-lengths, a travelling microscope with a screw accurate to 0·001 mm. is used to measure the positions of the bands or lines under investigation and a sufficient number of lines of the comparison spectrum. Care should be taken always to approach the line or band from the same direction, and after completing the measurements in one range the plate should be reversed, end to end, and a second run made. Reversal of the plate is very important when the lines measured differ much in definition or intensity, as individual observers show, as a rule, a tendency to set regularly off centre by an amount depending on the character of the line. Reduction to the mean setting is greatly facilitated if the scales of the microscope are graduated in both directions, as subtraction is thereby eliminated and there is no difficulty in identifying corresponding readings.

The microscope scale readings are converted to wave-lengths by use of a suitable interpolation formula. In the measurement of grating plates a linear formula,

$$\lambda = \lambda_0 + S.D$$

is used, where λ_0 is a constant depending on the zero of the scale, S is the scale reading and D is the dispersion of the spectrograph. Two carefully chosen lines of the comparison spectrum, one at either end of the range, are used to determine the constants of the formula ; the remaining comparison lines are used to construct a correction curve for deviations from this approximate formula. For prism spectrograms a three-constant formula,

$$\lambda = \lambda_0 + C/(S + S_0)$$

is generally used, where λ_0 is a constant depending on the material of the prism, C is a constant depending on the dimensions of the instrument, S is the scale reading and S_0 is a constant depending on the position of the scale zero. As before, the constants of the formula are obtained from carefully chosen standard lines, this time using one in the middle of the range as well as one at either end, and a correction curve is constructed from the remainder. In the measurement of short ranges the calculation is simplified by assuming an approximate round number for λ_0 and using two standard lines to give the other constants. With this procedure a correction curve is essential, and the corrections are larger than would be the case with the three constant formula, but there is the advantage that the curve does not contain a point of inflection. If the standard lines are converted to wave-numbers a linear formula,

$$\nu = \nu_0 + S.K$$

for wave-numbers may be used. This is much easier for use with a calculating machine, but the formula is still less accurate than the last and places a correspondingly greater burden on the correction curve.

DESCRIPTION OF PLATES

Below are given brief indications of the source used and of the type of spectrograph employed, viz., concave *grating*, *glass* prismatic instrument, or *E. 1* (large Littrow type) *E. 2* (medium) or *E. 3* (small) quartz spectrograph. Where the plate has been taken by other than one of the present authors this is indicated by the name in brackets.

Plates 1 to 6 all show positive enlargements, while the comparison spectra shown in Plates 7 and 8 are reproductions of negatives.

Plate 1. CaF. Calcium fluoride in carbon arc; glass.
CaO. Calcium carbonate in carbon arc; glass.
AlO High tension arc between Al electrodes; grating. (W. Jevons.)
AlCl Discharge tube; E. 1. (B. N. Bhaduri.)
SiO. Heated silica discharge tube; grating. (R. F. Barrow.)

Plate 2. Angstrom, Herzberg and Triplet Systems of CO. Positive column of discharge through CO_2; glass. (A. Fowler.)
Third positive and 5B bands of CO. Positive column of discharge through CO_2; E. 2. (A. Fowler.)
Fourth positive bands of CO. Positive column of discharge through CO_2; E. 2. (A. Fowler.)
CO^+, first negative. Negative glow of discharge through CO_2; E. 2. (A. Fowler.)
CO_2 (or CO_2^+). Negative glow of discharge through flowing CO_2; E. 2. (A. Fowler.)

Plate 3. N_2, first positive. Positive column of discharge through N_2; glass.
N_2, second positive. Positive column of discharge through N_2; E. 1. (R. C. Pankhurst.)
N_2^+. Negative glow of discharge through N_2; E. 2.
NO β. Active nitrogen; E. 2. (A. Fowler.)
NO γ. Positive column of discharge through air; E. 2.

Plate 4. H_2, blue region. Discharge through H_2; glass.
H_2, red region. Discharge through H_2; glass.
OH. Bunsen flame; E. 2.
CH. Discharge (? acetylene) (?).
NH. Discharge through flowing NH_3; E. 2. (R. W. Lunt.)
CuH. High-tension arc in hydrogen flame; E. 2.
ZnH. Zn in discharge through H_2; E. 2.
CdH. Hollow cathode; E. 2. (E. W. Foster and A. G. G.)

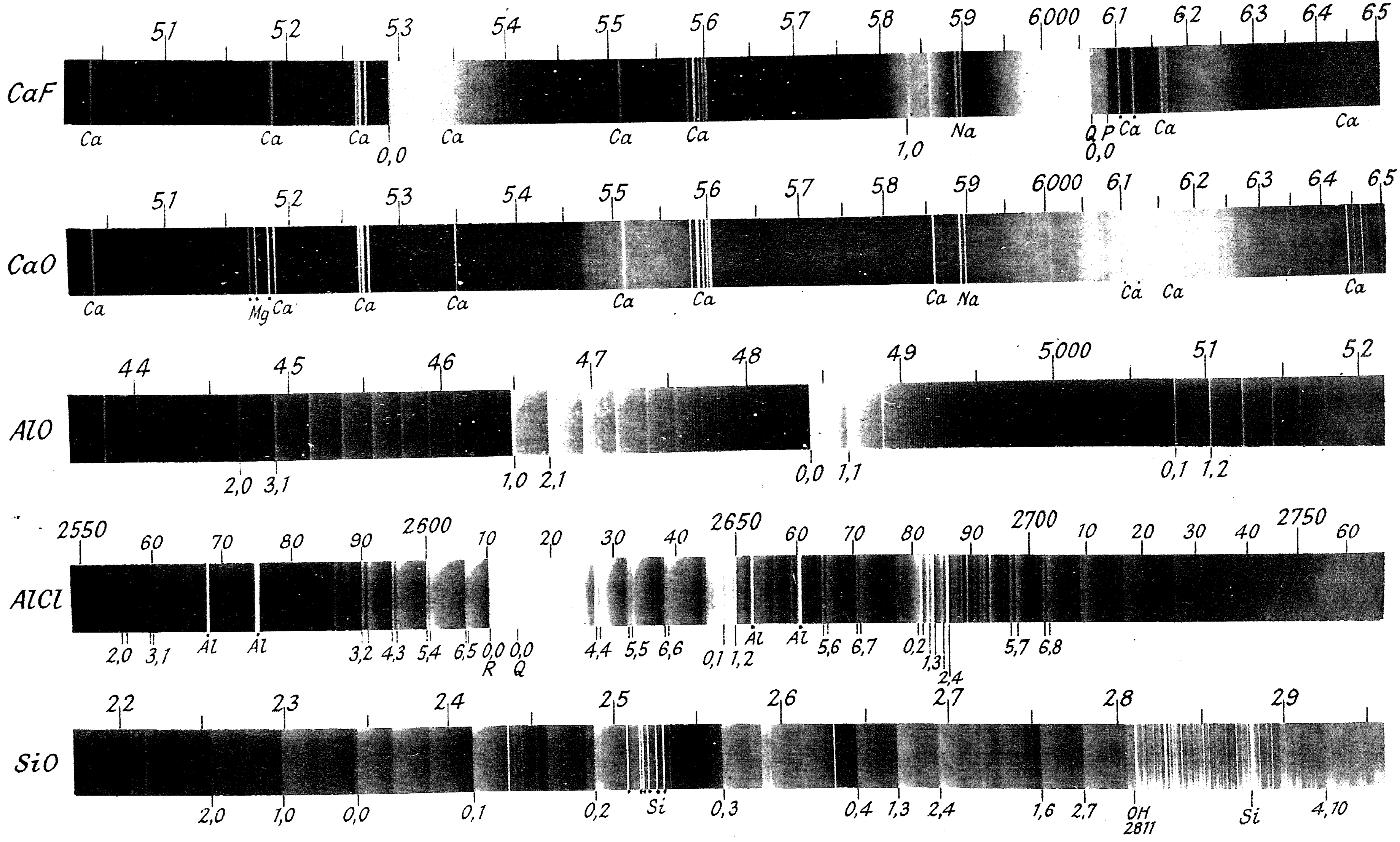
Plate 5. Bunsen flame. Inner cone; E. 2.
Ethylene flame. Inner cone; E. 2.
CO flame. E. 2; on process plate.
C_2, Swan. Discharge (? acetylene); glass (?).
CN, violet system; glass.
CN, red system. CCl_4 in active nitrogen; glass. (A. Fowler.)
CS and S_2. Sulphur in carbon arc; E. 3. (L. C. Martin.)
FeO. Iron carbonyl in flame; glass.

Plate 6. CuCl. Cuprous chloride in carbon arc; glass.
CuO. Arc in air between Cu electrodes; grating.
BO. Boric acid in carbon arc; glass.
SO and SO_2. Discharge through flowing SO_2; E. 3. (B. N. Bhaduri.)
SO_2 absorption. Hydrogen continuum; E. 2.
C_6H_6. Absorption by vapour; hydrogen continuum; E. 2.
CH_2O. Absorption by formaldehyde vapour; hydrogen continuum. E. 2. (G. H. Young.)
I_2. Absorption by iodine vapour; incandescent filament; glass.

Plate 7. Comparison spectra. Iron, copper and quartz mercury arcs, and neon discharge tube.

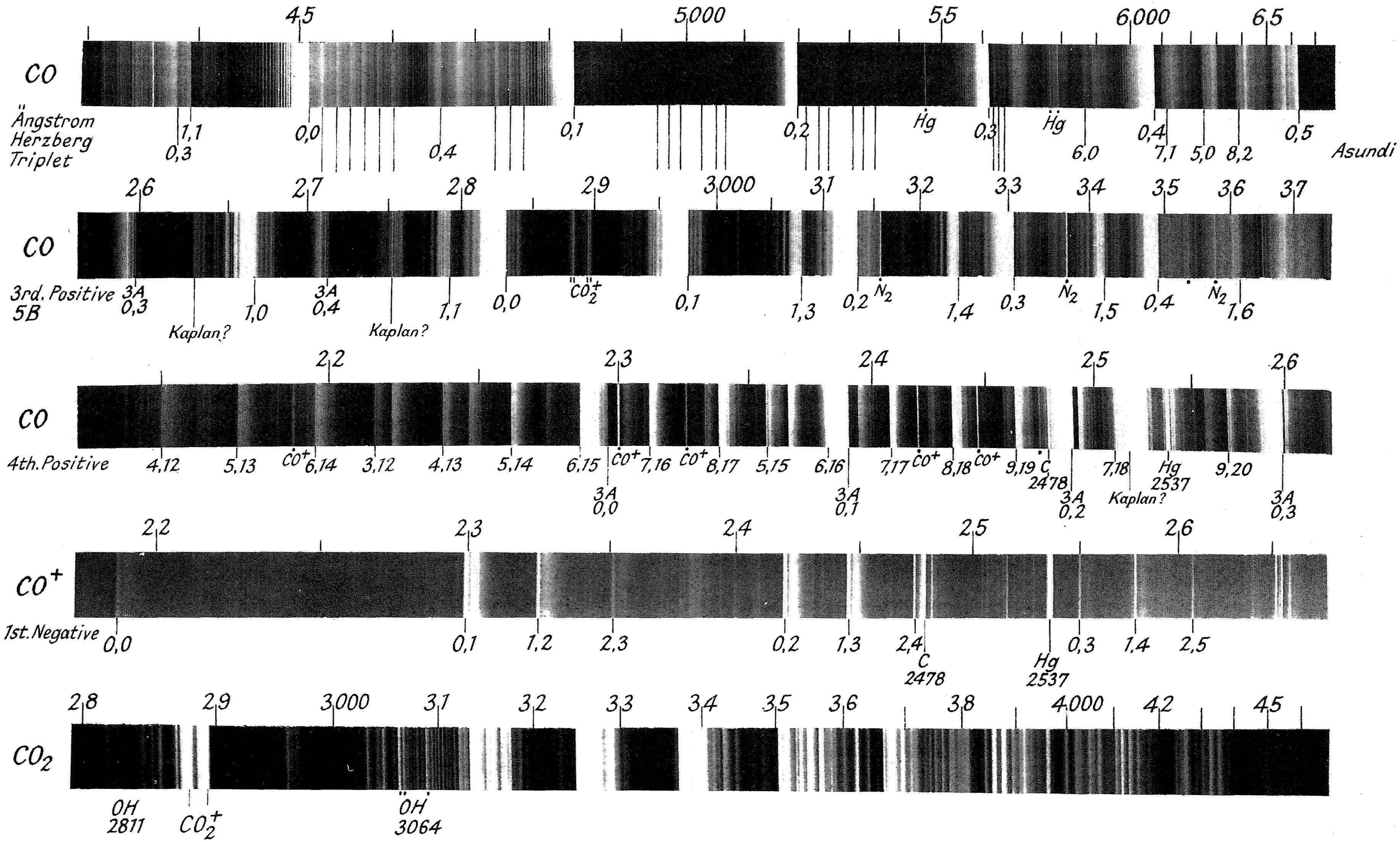
Plate 8. Comparison spectra. Iron arc.

PLATE I



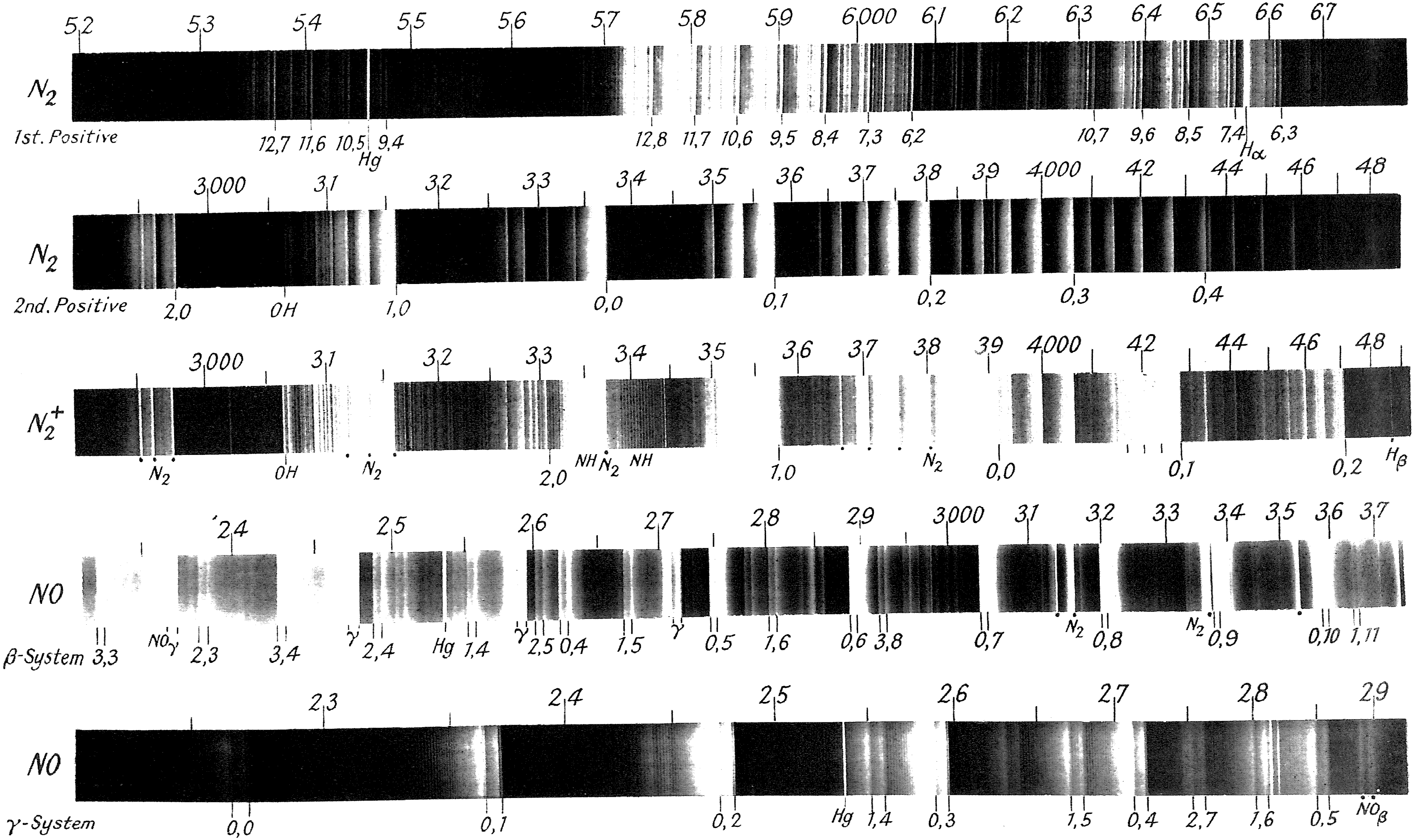
[Facing p. 208

PLATE 2



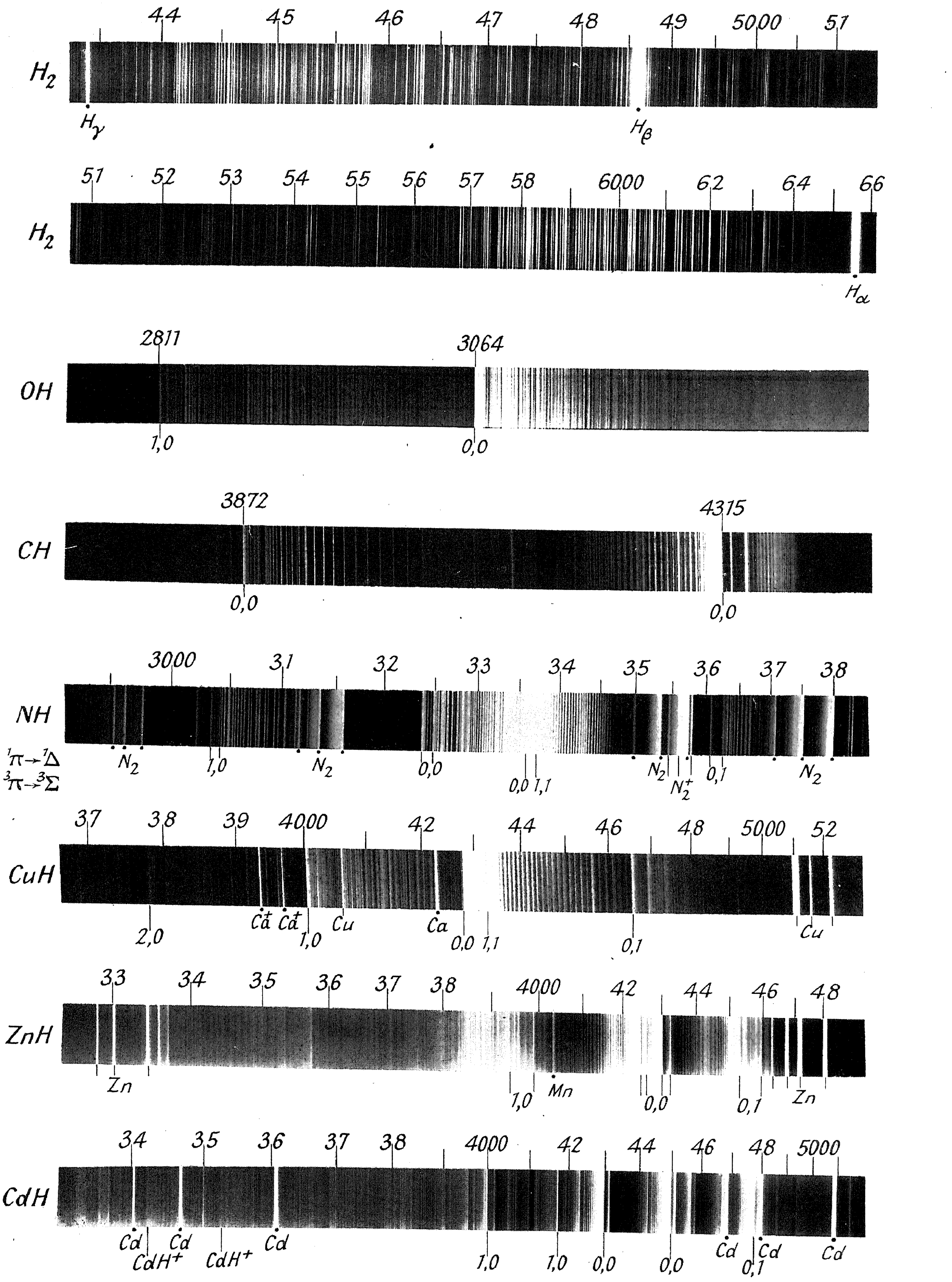
CO
Ängstrom
Herzberg
Triplet
Asundi
4,5
5,000
5,5
6,000
6,5
1,1
0,3
0,0
0,4
0,1
0,2
Hg
0,3
Hg
6,0
0,4
7,1
5,0
8,2
0,5
CO
3rd. Positive
5B
2,6
2,7
2,8
2,9
3,000
3,1
3,2
3,3
3,4
3,5
3,6
3,7
3A
0,3
Kaplan?
1,0
3A
0,4
Kaplan?
1,1
0,0
CO_2^+
0,1
1,3
0,2
N_2
1,4
0,3
N_2
1,5
0,4
N_2
1,6
CO
4th. Positive
2,2
2,3
2,4
2,5
2,6
4,12
5,13
CO^+
6,14
3,12
4,13
5,14
6,15
3A
0,0
CO^+
7,16
CO^+
8,17
5,15
6,16
3A
0,1
7,17
CO^+
8,18
CO^+
9,19
C
2478
3A
0,2
7,18
Kaplan?
Hg
2537
9,20
3A
0,3
CO^+
1st. Negative
2,2
2,3
2,4
2,5
2,6
0,0
0,1
1,2
2,3
0,2
1,3
2,4
C
2478
Hg
2537
0,3
1,4
2,5
CO_2
2,8
2,9
3,000
3,1
3,2
3,3
3,4
3,5
3,6
3,8
4,000
4,2
4,5
OH
2811
CO_2^+
OH
3064

PLATE 3

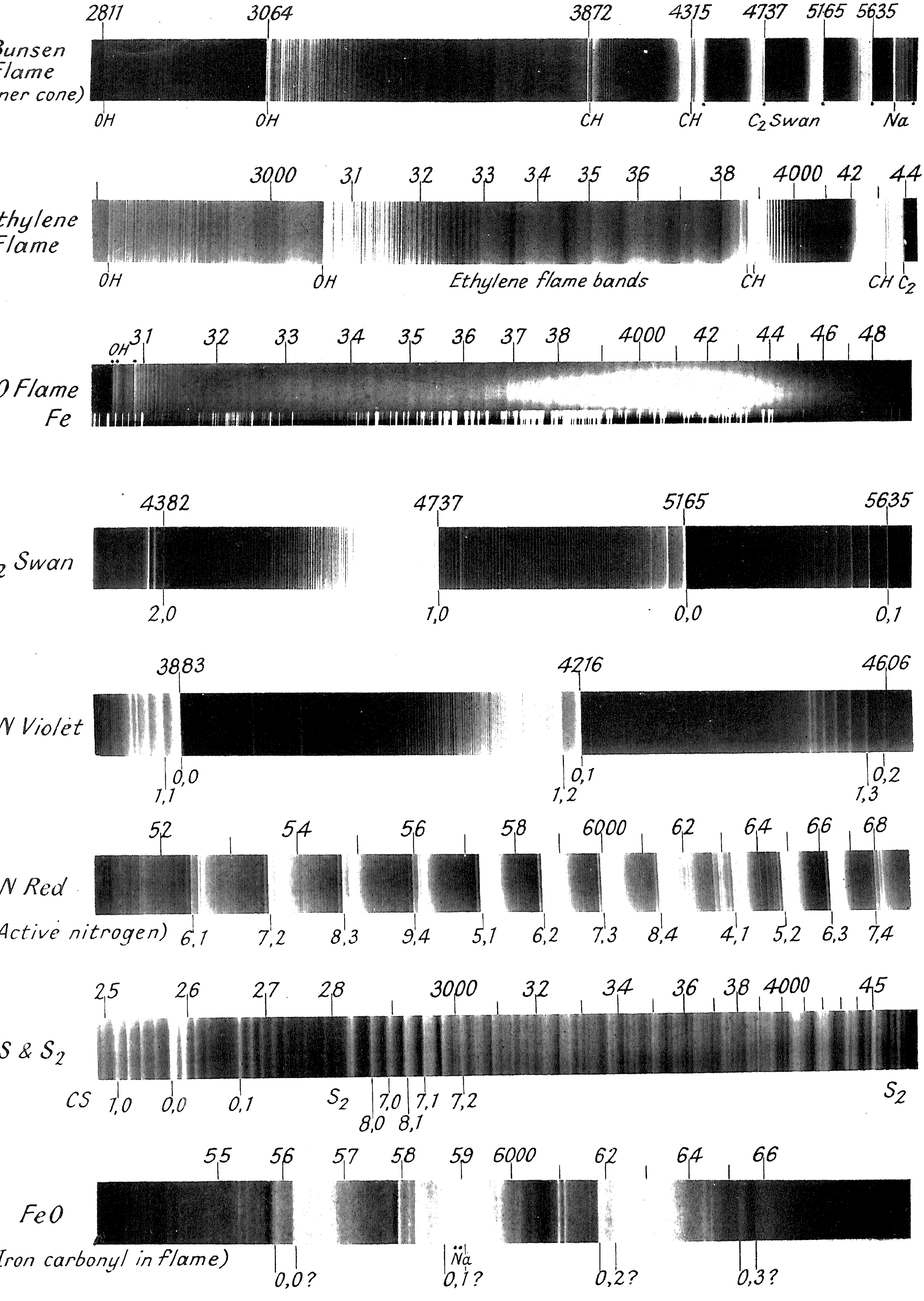


N_2
1st. Positive
5,2 5,3 5,4 5,5 5,6 5,7 5,8 5,9 6,000 6,1 6,2 6,3 6,4 6,5 6,6 6,7
12,7 11,6 10,5 9,4 Hg 12,8 11,7 10,6 9,5 8,4 7,3 6,2 10,7 9,6 8,5 7,4 Hα 6,3
N_2
2nd. Positive
3,000 3,1 3,2 3,3 3,4 3,5 3,6 3,7 3,8 3,9 4,000 4,2 4,4 4,6 4,8
2,0 OH 1,0 0,0 0,1 0,2 0,3 0,4
N_2^+
3,000 3,1 3,2 3,3 3,4 3,5 3,6 3,7 3,8 3,9 4,000 4,2 4,4 4,6 4,8
N_2 OH N_2 2,0 NH N_2 NH 1,0 N_2 0,0 0,1 0,2 H_β
NO
β-System
2,4 2,5 2,6 2,7 2,8 2,9 3,000 3,1 3,2 3,3 3,4 3,5 3,6 3,7
3,3 NO γ 2,3 3,4 γ 2,4 Hg 1,4 γ 2,5 0,4 1,5 γ 0,5 1,6 0,6 3,8 0,7 N_2 0,8 N_2 0,9 0,10 1,11
NO
γ-System
2,3 2,4 2,5 2,6 2,7 2,8 2,9
0,0 0,1 0,2 Hg 1,4 0,3 1,5 0,4 2,7 1,6 0,5 NO β

PLATE 4



44 45 46 47 48 49 5000 51
H2
Hγ Hβ
51 52 53 54 55 56 57 58 6000 62 64 66
H2
Hα
2811 3064
OH
1,0 0,0
3872 4315
CH
0,0 0,0
3000 31 32 33 34 35 36 37 38
NH
1π→1Δ
3π→3Σ
N2 1,0 N2 0,0 0,0 1,1 N2 N2+ 0,1 N2
37 38 39 4000 42 44 46 48 5000 52
CuH
2,0 Ca+ Ca+ 1,0 Cu Ca 0,0 1,1 0,1 Cu
33 34 35 36 37 38 4000 42 44 46 48
ZnH
Zn 1,0 Mn 0,0 0,1 Zn
34 35 36 37 38 4000 42 44 46 48 5000
CdH
Cd CdH+ Cd CdH+ Cd 1,0 1,0 0,0 0,0 Cd 0,1 Cd Cd


2811 3064 3872 4315 4737 5165 5635
Bunsen Flame (inner cone)
OH OH CH CH C_2 Swan Na
3000 31 32 33 34 35 36 38 4000 42 44
Ethylene Flame
OH OH Ethylene flame bands CH CH C_2
OH 31 32 33 34 35 36 37 38 4000 42 44 46 48
O Flame
Fe
4382 4737 5165 5635
C_2 Swan
2,0 1,0 0,0 0,1
3883 4216 4606
N Violet
1,1 0,0 1,2 0,1 1,3 0,2
52 54 56 58 6000 62 64 66 68
N Red
(Active nitrogen) 6,1 7,2 8,3 9,4 5,1 6,2 7,3 8,4 4,1 5,2 6,3 7,4
25 26 27 28 3000 32 34 36 38 4000 45
CS & S_2
CS 1,0 0,0 0,1 S_2 8,0 7,0 8,1 7,1 7,2 S_2
55 56 57 58 59 6000 62 64 66
FeO
(Iron carbonyl in flame) 0,0? Na 0,1? 0,2? 0,3?

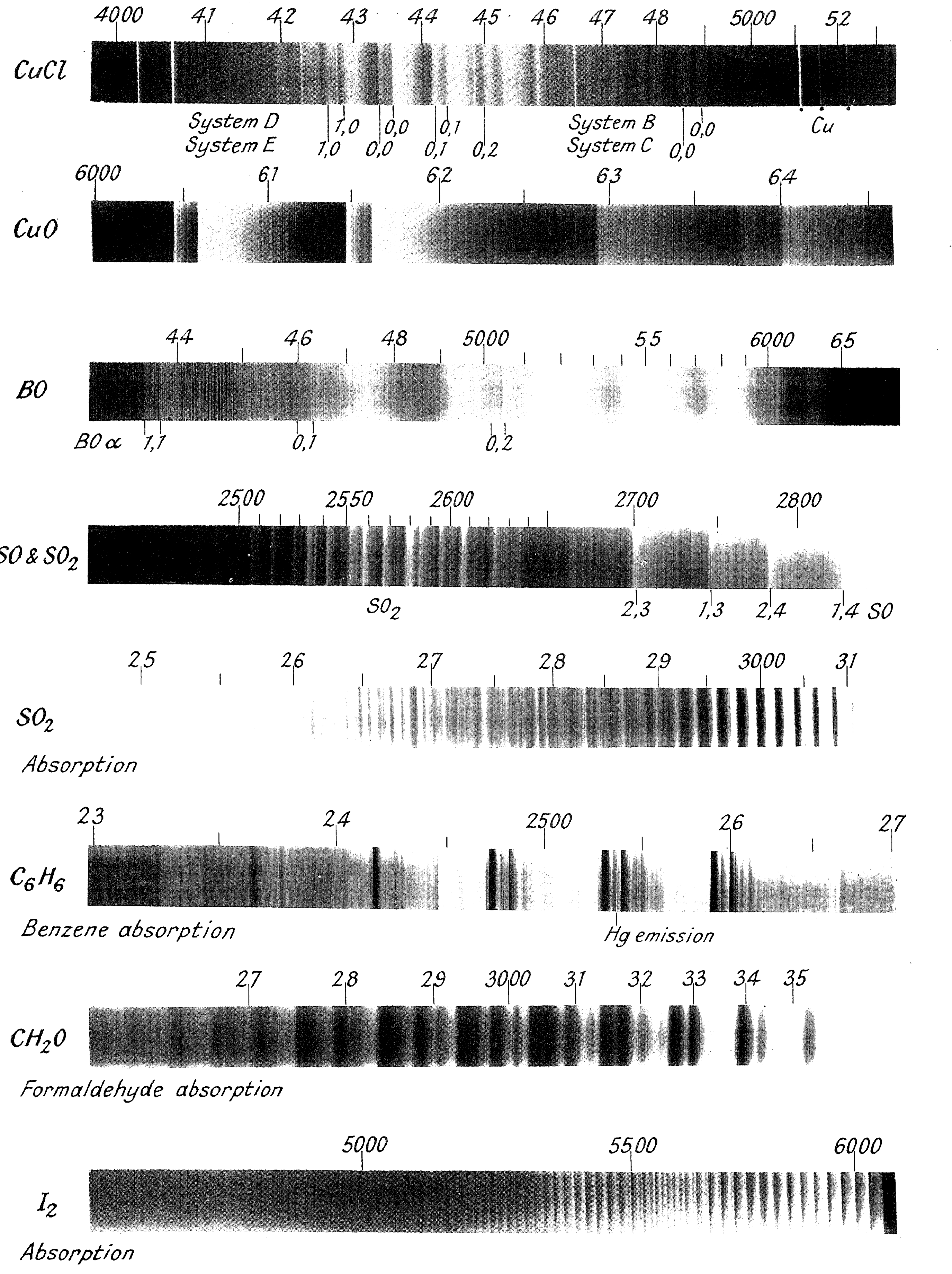
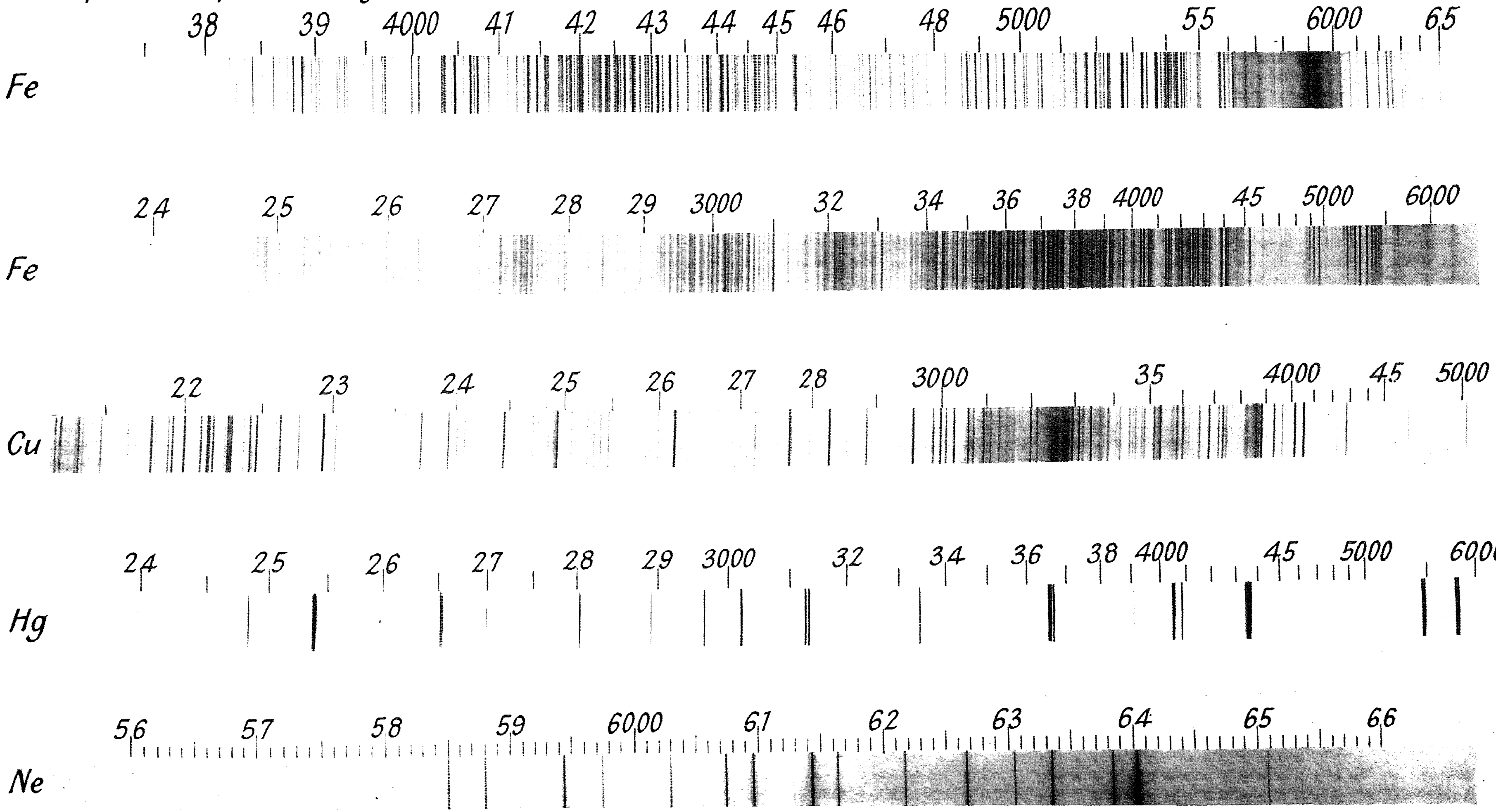
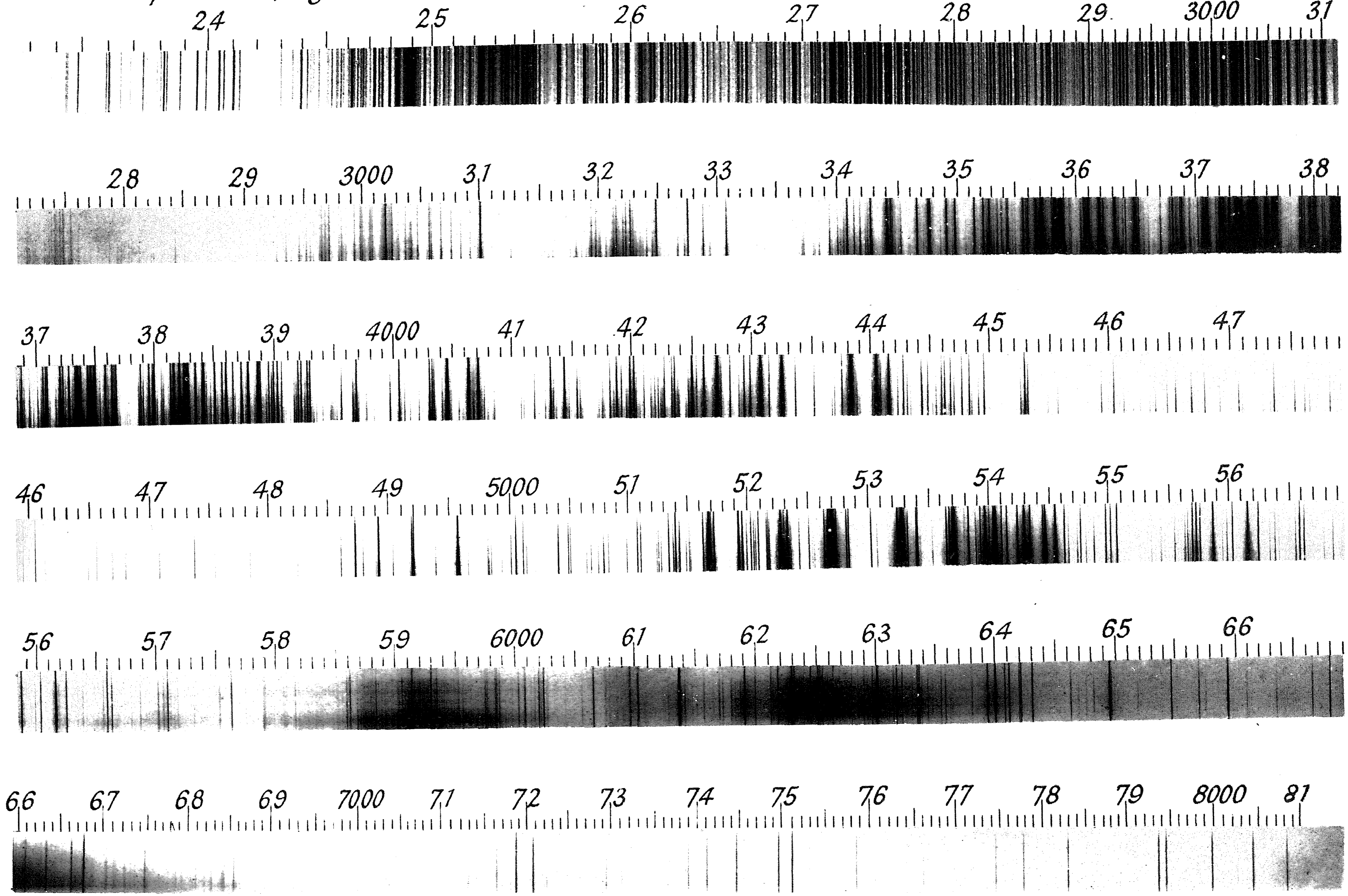

4000 41 42 43 44 45 46 47 48 5000 52
CuCl
System D
System E
1,0 0,0 0,1
1,0 0,0 0,1 0,2
System B
System C
0,0
0,0
Cu
6000 61 62 63 64
CuO
44 46 48 5000 55 6000 65
BO
BO α 1,1 0,1 0,2
2500 2550 2600 2700 2800
SO & SO_2
SO_2
2,3 1,3 2,4 1,4 SO
2,5 2,6 2,7 2,8 2,9 3000 31
SO_2
Absorption
23 24 2500 26 27
C_6H_6
Benzene absorption
Hg emission
27 28 29 3000 31 32 33 34 35
CH_2O
Formaldehyde absorption
5000 5500 6000
I_2
Absorption

PLATE 7

Comparison Spectra (negatives)



Iron Arc Spectrum (negatives)



In measuring band heads the crosswires of the microscope should not be set on the extreme edge of the band, but an attempt should be made to allow for the finite width of a line by setting half a line width within the head. Unless this is done the value obtained for the wave-length of the head may vary considerably from spectrograph to spectrograph, and if a wide slit is used may lead to discrepancies of several angstroms.

In measuring very faint lines it is generally found to be of some slight advantage to use blue light to illuminate the plate ; faint lines appear a little more distinctly with the shorter wave-length illumination, possibly on account of greater scattering by the grains of the plate.

Spurious Bands. When using a quartz spectrograph care should be taken to avoid the light from the source becoming polarised before reaching the spectrograph. With polarised light, interference between the ordinary and extraordinary rays may introduce into a continuum a banded structure not unlike a diffuse band spectrum. The bands are usually too regular to be mistaken for a real molecular spectrum when strong and isolated, but if superimposed on a band system may cause errors in measurements of wave-length and intensity. The light may be polarised if reflectors are used to bring the image on the slit. Light from a discharge tube is often slightly polarised, probably by reflections within the tube.

If plates are not rocked or brushed during development broad lines or bands may become more strongly developed at the edges than in the centre, giving a spurious resolution into two.

With long exposures in a well-lit room it is possible for sufficient diffuse daylight to enter the slit to record the solar spectrum with the stronger Fraunhofer lines, particularly the H and K lines of Ca^+. If their origin is not recognised, these may be attributed to absorption bands from the source in use.

APPENDIX

Persistent Atomic Lines

In the following table the most persistent atomic lines are given for each element. In addition to the " raies ultimes " usually quoted, we have given in many cases additional lines to cover regions in which there are no " raies ultimes."

For elements possessing a simple readily excited spectrum, *e.g.*, metals like Na, Ca, Al, intensities are quoted on a scale of 10 for the strongest line. For elements whose spectra are less distinctive and less easily excited, *e.g.*, Fe, W, the intensities are given on a scale of 8. For elements whose spectra appear with difficulty, *e.g.*, the non-metals, O, Cl, the intensities are given on a scale of only 5 for the strongest line. Lines which are readily observed in absorption are indicated by the letter *a* following the intensity. The intensities given are in most cases those for arc sources, or other mild conditions of excitation ; for gases they refer to Geissler tube excitation.

A

8115·31	5
7503·87	4
7067·22	3
6965·43	4
4348·0	5

Ag

5465·48	7
5209·06	8
3382·89	10*a*
3280·67	10*a*

Al

3961·54	10*a*
3944·02	9*a*
3092·72	8*a*
3082·16	8*a*

As

2860·46	6
2780·20	6
2349·84	8
2288·14	6

Au

4792·62	6
2675·95	8*a*
2427·96	8*a*

B

2497·73	5
2496·78	4

Ba

5777·7	9
5535·53	10*a*
5519·11	6
3421·0	8

Ba^{+}

4934·09	8
4554·04	10

Be

4573·69	5
3321·35	6
3321·09	6
2650·78	5
2348·62	10*a*

Be^{+}

3131·06	8
3130·42	6

Bi

4722·55	8
3067·73	10
2989·04	7
2938·30	8
2897·98	9

Br

4816·72	4
4785·48	5
4704·83	5

C

2478·57	5

C^{+}

4267·27	5

Ca

5602·84	5
to	
5581·96	
5270·27	4
to	
5261·70	
4454·78	8
4434·96	7
4425·44	6
4318·65	6
to	
4283·10	
4226·73	10*a*

Ca^{+}

3968·47	10
3933·67	10

Cb (Nb)

4079·73	5
4058·94	8

Cd

6438·47	10
5085·82	6
4799·91	6
3610·51	9
3466·20	9
3403·65	8
3261·05	10
2288·03	9*a*

Ce

4628·15	
to	
4460·21	
4186·60	8
4165·61	4
4040·76	7
4012·40	6

Cl

4819·46	4
4810·06	5
4794·54	5

Co

3465·80	6
3453·51	8
3405·12	6
2407·26	4

Cr

5208·43	6
5206·04	6
5204·54	6
4289·72	9*a*
4274·80	9*a*
4254·34	10*a*
3605·35	9
3593·48	9
3578·69	10

Cs

8943·50	10*a*
8521·15	10*a*
4593·18	7*a*
4555·36	8*a*

Cu

5220·06	4
5218·20	5
5153·26	4
5105·55	4
3273·96	9*a*
3247·55	10*a*

Dy

4211·72	4
4167·97	1
4077·98	3
4046·00	3
4000·50	8

Er

3906·34	5
3692·65	4
3499·12	3

Eu

4205·03	5
4129·73	3

F

6902·46	4
6856·01	5

Fe

4957·61	5
4920·52	5
4891·50	4
3734·87	7
3719·94	7
3581·20	7
3570·10	7
3475·46	7
3465·86	7
3020·65	7
2522·86	7
2488·15	7
2483·28	8

Ga

4172·05	10*a*
4033·01	10*a*

Gd

3768·40	2
3646·19	10

Ge

4226·61	7
3269·49	7
3039·08	8
2754·59	8
2709·61	8
2651·18	8

H

6562·79	8
4861·33	6
4340·47	4

He

5875·62	5
4685·75	2
3888·65	5

Hf

4093·17	1
3134·72	3
3072·88	3
2940·77	3
2916·48	2
2904·41	1
2898·25	2

Hg

5790·66	5
5769·60	5
5460·73	6
4358·34	6
4046·56	6
3650·15	6
2536·52	9*a*
1849·6	10*a*

Ho

3891·02	5
3748·19	1

I

5464·61	3
5161·19	5
3288·3	—
2062·38	—

In

4511·31	10*a*
4101·76	8
3256·08	8
3039·36	7

Ir

3513·67	5
3220·79	5
3133·34	5

K

7698·98	10*a*
7664·91	10*a*
4047·22	9*a*
4044·16	9*a*

Kr

5870·92	5
5570·29	5

La

6249·93	4
5930·65	3
4429·90	5
4333·80	5
4123·23	6
4086·71	6
3949·10	8
3337·49	7

Li

6707·86	10*a*
6103·64	5
4602·99	4
3232·61	3*a*

Lu

4518·54	5
2911·39	2
2894·84	1

Mg

5183·62	8
5172·68	7
5167·33	6
3838·26	7
3832·31	6
3096·92	8
2852·13	10*a*

Mg^+

2802·71	8
2795·54	8

Mn

6021·79	3
6016·64	3
6013·50	3
4034·49	10*a*
4033·07	10*a*
4030·76	10*a*
2798·27	6

Mo

3902·96	7
3864·12	8
3798·26	8
3193·98	6
3170·34	6
3132·60	6

N

4935·03	—
4447·0	—
4109·94	5
4099·94	2

N^+

5679·5	5
5666·6	5

Na
5895·93 9*a*
5889·96 10*a*
3302·94 4*a*
3302·34 4*a*

Nd
4303·61 5
4177·34 1
3951·15 2

Ne
6402·25 8
5852·49 8
5400·56 8

Ni
3524·54 7
3515·06 4
3446·26 6
3414·77 8

O
7771·95 5
6158·21 —
5330·65 —
4368·30 —
3947·29 —

Os
4420·46 3
4260·85 3
3267·94 6
3058·66 6
2909·08 8
2488·55 6

P
2554·93 5
2553·28 8
2535·65 8
2534·01 6

Pb
4057·83 10
3683·47 8
3639·58 6
2833·07 5
2170·00 —

Pd
3634·68 2
3609·55 2
3516·95 4
3421·23 6
3404·59 8

Pr
4225·34 1
4189·52 2
4179·43 5
4062·83 3

Pt
3064·71 8
2659·44 8

Ra
4825·94

Rb
7947·63 10*a*
7800·23 10*a*
6298·6 5
4215·58 8*a*
4201·81 8*a*

Rh
4374·82 4
3692·35 4
3434·90 8

Ru
3728·02 4
3726·93 4
3498·95 8
3436·74 4

S
4696·25 3
4695·45 4
4694·13 5

Sb
3267·48 4
3232·52 2
2877·92 8
2598·08 8
2528·53 8
2311·50 6
2175·89 8
2068·38 8

Sc
4023·72 8
4020·42 5
3911·81 8
3907·48 5

Se
4742·25 3
4739·03 4
4730·78 5
2062·79 4
2039·85 5

Si
3905·52 1
2881·59 8
2528·52 4
2524·12 4
2516·12 5
2506·90 4

Sm
4424·35 5
4390·87 2

Sn
5731·70 1
3262·33 9
3175·05 10
3034·12 8
2863·32 10
2839·99 10
2706·50 8

Sr
4962·26 3
4872·49 2
4832·08 5
4607·33 10

Sr$^+$
4215·52 6
4077·71 10

Ta
6485·36 1
3318·85 5
3311·14 5
2714·68 8

Tb
3874·19 5
3848·76 2
3561·75 5
3509·18 5

Te
2769·65 4
2385·78 5
2383·27 5
2142·75 4

Th
4019·14
3601·05
3538·75

Ti
4999·51 2
4981·73 3
4536·05 4
to
4533·25
3998·64 6
3371·46 6
3341·87 8

Ti$^+$
3372·80 6
3361·22 6
3349·41 6
3349·04 5

Tl
5350·47 10*a*
3775·73 9
3519·24 7
2918·32 2
2767·87 2

Tu
3761·91 4
3761·34 5
3462·21 4

U

5527·84	
4241·68	
3672·58	

V

4460·31	5
4408·52	5
to	
4379·24	8
4128·07	8
3185·41	8
3183·99	8

W

4302·11	6
4294·62	5
4008·76	8
3617·52	3

Xe

4671·22	5
4624·27	2
4500·98	1

Y

4674·85	4
4643·69	2
4374·95	4
4142·87	6
4102·38	8
3774·33	6
3710·30	6
3242·28	6

Yb

3988·01	5
3694·20	3
3289·73	3

Zn

6362·35	6
4810·53	10
4722·16	10
4680·14	9
3344·91	9
2138·61	5*a*

Zr

4710·07	1
4687·80	2
3601·19	5
3547·68	3
3519·61	2
3481·15	1

Zr$^+$

3572·47	1
3496·21	2
3438·23	3
3391·98	5

For the most complete and recent work on line spectra, the reader is referred to "Massachusetts Institute of Technology Wave-length Tables," edited by G. R. Harrison, (John Wiley and Sons, 1939, London: Chapman and Hall).

Conversion of Wave-lengths on Rowland's Scale to International Angstroms

Range in A	Correction (subtract)	Range in A	Correction (subtract)
2950–3125	0·12	5400–5500	0·21
3125–3250	0·13	5500–6050	0·22
3250–3450	0·14	6050–6500	0·21
3450–4150	0·15	6500–6570	0·22
4150–4350	0·16	6570–6750	0·23
4350–4550	0·17	6750–6850	0·24
4550–5125	0·18	6850–7000	0·25
5125–5300	0·17	7000–7200	0·26
5300–5325	0·18	7200–7400	0·27
5325–5375	0·19	7400–7700	0·28
5375–5400	0·20		

Conversion of Wave-lengths in Air to Wave-lengths in Vacuo

λ_{air}	add	λ_{air}	add	λ_{air}	add	λ_{air}	add
15,000	4·10	7800	2·14	5800	1·60	3800	1·07
14,000	3·83	7600	2·09	5600	1·55	3600	1·02
13,000	3·55	7400	2·04	5400	1·50	3400	0·97
12,000	3·28	7200	1·98	5200	1·44	3200	0·92
11,000	3·01	7000	1·93	5000	1·39	3000	0·87
10,000	2·74	6800	1·87	4800	1·34	2800	0·82
9500	2·60	6600	1·82	4600	1·28	2600	0·78
9000	2·46	6400	1·77	4400	1·23	2400	0·73
8500	2·33	6200	1·71	4200	1·18	2200	0·69
8000	2·20	6000	1·66	4000	1·13	2000	0·65

Physical Constants, etc.

c velocity of light, $2{\cdot}9986 \times 10^{10}$ cm./sec.
e electronic charge, $4{\cdot}80 \times 10^{-10}$ E.S.U.
h Planck's constant, $6{\cdot}62 \times 10^{-27}$ erg. sec.
k Boltzmann factor, $1{\cdot}381 \times 10^{-16}$ erg./deg.
N Avagadro's number, $6{\cdot}02 \times 10^{23}$ mols/gm. mol.
n Loschmidt's number, $2{\cdot}685 \times 10^{19}$ mols/c.c. at N.T.P.
m_0 mass of electron, $9{\cdot}1 \times 10^{-28}$ gm.
m_H mass of hydrogen atom, $1{\cdot}66 \times 10^{-24}$ gm.
R_H Rydberg constant for hydrogen, $109677{\cdot}7$ cm.$^{-1}$
R_∞ Rydberg constant, infinite mass, $109737{\cdot}1$ cm.$^{-1}$
1 A (angstrom) $= 10^{-8}$ cm.
1 μ (micron) $= 10^{-4}$ cm.
1 gm. calorie $= 4{\cdot}185 \times 10^{7}$ ergs.
1 electron-volt $= 1{\cdot}60 \times 10^{-12}$ ergs.
1 electron-volt $= 8066$ cm^{-1} (wave-numbers).
1 cm.$^{-1}$ $= 2{\cdot}86$ gm. cal./mol.

AUTHOR INDEX

SUBJECT INDEX

Chemical symbols of molecules are given in the tables of "Individual Band Systems" in alphabetical order and are not therefore included in this index; those chemical symbols given here are those which, for some reason, are listed in the book under a different symbol.

SiS (*contd.*)

WEAK SYSTEM, λλ6169–3491

Appearance. Degraded to the red. An extensive system of relatively weak bands, which are spaced at regular intervals.

An additional weak system around 2340 A. has been reported in absorption by Vago and Barrow (*Nature, Lond.*, **157**, 77 (1946)).

SiSe

Occurrence. Heavy-current discharge through quartz tube containing aluminium selenide. Also in absorption.

Appearance. Degraded to the red. Single-headed bands.

Reference. R. F. Barrow, *Proc. Phys. Soc.*, **51**, 267. (1939)†.

Strong bands :—

λ	*I*	*v′, v″*	λ	*I*	*v′, v″*
3406·0	7	1, 6	3145·3	9	0, 1
3342·2	9	1, 5	3106·4	9	1, 1
3323·7	8	0, 4	3051·8	8	1, 0
3262·4	10	0, 3	3015·8	7	2, 0
3203·0	10	0, 2	2981·1	6	3, 0

A weak system around 2600 A. has been reported in absorption by Vago and Barrow (*Nature, Lond.*, **157**, 77 (1946)).

SiTe

Occurrence. Heavy current through quartz tube containing aluminium and tellurium. Also in absorption.

Appearance. Degraded to the red. Single-headed bands.

Reference. R. F. Barrow, *Proc. Phys. Soc.*, **51**, 45. (1939)†.

Strong bands :—

λ	*I*	*v′, v″*	λ	*I*	*v′, v″*
3763·9	8	1, 5	3556·1	10	0, 1
3745·2	9	0, 4	3514·3	10	1, 1
3680·3	9	0, 3	3456·2	8	1, 0
3617·3	10	0, 2	3417·0	7	2, 0

A weak system around 2900 A. has been reported in absorption by Vago and Barrow (*Nature, Lond.*, **157**, 77 (1946)).

SmO

Occurrence. Samarium salts in oxy-hydrogen flame.

Reference. G. Piccardi, *Rend. Accad. Linc.*, **21**, 589. (1935).

The following are the strongest heads :—

λ	*I*	λ	*I*
6570·1	6	6485·5	7
6557·2	8	6349·5	8
6533·5	9	6034·4	6
6510·9	10	5822·4	7

SnBr

Occurrence. Heavy-current discharge through flowing tin tetrabromide vapour.
Reference. W. Jevons and L. A. Bashford, *Proc. Phys. Soc.*, **49**, 554. (1937)†.

VIOLET SYSTEM, λλ4255–3709

Appearance. Degraded to the red.
Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.
Strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
4196·5	6	0, 3 i	3820·8	6	0, 2 ii
4153·9	8	0, 2 i	3798·4	7	1, 2 ii
4112·1	10	0, 1 i	3785·8	7	0, 1 ii
4070·7	10	0, 0 i	3750·8	8	0, 0 ii
3833·7	6	1, 3 ii	3729·4	6	1, 0 ii

ULTRA-VIOLET SYSTEM, λλ3428–3021

Appearance. Degraded to shorter wave-lengths. Two progressions which look rather like sequences.
Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.
Strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
3372·0	4	0, 4 i	3112·2	4	0, 4 ii
3344·6	5	0, 3 i	3089·2	5	0, 3 ii
3317·2	6	0, 2 i	3066·4	6	0, 2 ii
3290·4	7	0, 1 i	3043·6	7	0, 1 ii
3263·7	*	0, 0 i	3021·1	4	0, 0 ii

* Masked by Sn line 3262·33.

SnCl

There are three band systems in the ultra-violet, λλ3910–3486, λλ3405–2830 and λλ2450–2250 ; there are also two regions of continuous spectrum, from λ4900 to λ3950 and in the far ultra-violet.
Occurrence. All systems have been obtained in absorption by strongly-heated $SnCl_2$, and the first two band systems have been observed in emission from an uncondensed discharge through tin tetrachloride vapour.
References. W. Jevons, *P.R.S.*, **110**, 365. (1926)†.
W. F. C. Ferguson, *P.R.*, **32**, 607. (1929).
C. A. Fowler, *P.R.*, **62**, 141. (1942)†.

λλ3910–3486 SYSTEM

Appearance. Degraded to red. Two strong sequences.
Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.
Heads of strong bands :—

λ	I	v′, v″	λ	I	v′, v″
3786·3	2	3, 3 i	3511·2	1	3, 3 ii
3776·6	5	2, 2 i	3502·5	2	2, 2 ii
3767·3	8	1, 1 i	3494·7	8	1, 1 ii
3758·5	10	0, 0 i	3487·8	10	0, 0 ii

SnCl (*contd.*)

λλ3405–2830 System

Appearance. Degraded to shorter wave-lengths. Strong $SnCl^{35}$ heads with weaker $SnCl^{37}$ heads visible in a few bands.

Transition. $^2\Sigma \rightarrow {}^2\Pi$, ground state.

Heads of strong bands only :—

λ	I	v′, v″	λ	I	v′, v″
3271·5	5	0, 2 i	3004·5	6	0, 1 ii
3234·4	7	0, 1 i	2973·4	8	0, 0 ii
3197·8	7	0, 0 i	2966·3	3	1, 1 ii
3154·5	7	1, 0 i	2959·3	5	2, 2 ii
3112·4	5	2, 0 i	2935·8	10	1, 0 ii
3105·2	4	3, 1 i	2899·4	7	2, 0 ii
3036·4	4	0, 2 ii	2893·0	5	3, 1 ii

λλ2450–2250 System

Appearance. Degraded to shorter wave-lengths.

Transition. Probably $^2\Pi \rightarrow {}^2\Pi$, ground state.

The following are the strongest bands in absorption :—

λ	I	v′, v″
2307·4	5	0, 1
2288·9	9	0, 0
2268·6	10	1, 0
2248·9	8	2, 0

SnF

Occurrence. In absorption.

Appearance. Four band systems, all degraded to shorter wave-lengths, and two regions of continuous absorption.

Reference. F. A. Jenkins and G. D. Rochester, *P.R.*, 52, 1135. (1937)†.

The P heads of the strong bands are given below. No intensities are available, but the high-frequency components of the doublet systems (denoted by ii below) are stated to be the stronger.

System A $^2\Sigma \leftarrow X\ {}^2\Pi$, Ground State, λλ3260–2660

This is the strongest system. Close double-headed bands, separation about 1A.

λ	v′, v″	λ	v′, v″
3199·7	0, 1 i	2969·4	1, 2 ii
3141·2	0, 0 i	2927·9	0, 0 ii
3076·2	1, 0 i	2871·4	1, 0 ii
3020·7	0, 2 ii	2817·6	2, 0 ii
2978·2	0, 1 ii		

System B $^2\Delta \leftarrow X\ {}^2\Pi$, λλ2635–2556

Close double-headed bands. System partly obscured by continuum.

λ	v′, v″
2635·4	0, 1
2595·5	0, 0
2556·3	1, 0

SnF (*contd.*)

SYSTEM C $^2\Pi \leftarrow$ X $^2\Pi$, λλ2350–2100

This is a weak system of single-headed bands.

λ	v′, v″
2348·2	1, 0 i
2222·8	0, 1 ii
2194·7	0, 0 ii
2162·5	1, 0 ii

SYSTEM D $^2\Delta \leftarrow$ X $^2\Pi$, λλ2300–2060

A strong system of close double-headed bands.

λ	v′, v″	λ	v′, v″
2296·7	0, 1 i	2184·3	0, 1 ii
2266·3	0, 0 i	2157·1	0, 0 ii
2236·1	1, 1 i	2129·3	1, 0 ii

CONTINUA

E $\leftarrow$ X $^2\Pi$, λ2500–2370.
F $\leftarrow$ X $^2\Pi$. In far ultra-violet below 2100 A.

SnH

4050 A SYSTEM

Occurrence. Obtained by Watson and Simon from a tin arc in hydrogen at 5 atmospheres pressure.
Appearance. Complex bands degraded to the red.
Transition. $^2\Delta \rightarrow {}^2\Pi$, ground state.
Reference. W. W. Watson and R. Simon, *P.R.*, **55**, 358. (1939).

With low dispersion, heads are observed at 4054 A. and 4447 A., followed by stronger heads at 4071 A. and 4466 A. The latter are shown to be complex by high dispersion.

$^RQ_{21dc,cd}$	$R_{1dc,cd}$	Q_2	$^QR_{12}$
4071·3	4071·8	4466·6	4466·0
4071·4	4070·8		

The band is assumed to be the (0, 0) band of the system.

6095 A SYSTEM

Under similar conditions Watson and Simon observed a band to longer wave-lengths with heads at 6095 A., 6063 A., and 6022 A., accompanied by a weaker band with a head at 6214 A. Further bands to the red and infra-red are mentioned but no details are given.

RED SYSTEM

Appearance. Watson and Simon in a later paper report further bands degraded to the red with prominent heads at 6745, 6892 and 7030 A. with a pile up of lines at 6931 A. These authors consider it probable that further bands lie to the infra red.
Transition. Probably $^2\Sigma \rightarrow {}^2\Pi$, ground state.
Reference. W. W. Watson and R. Simon, *P.R.*, **57**, 708. (1940).

SnO

Occurrence. In arcs and flames containing tin salts; Connelly used a high-tension discharge through a flame containing $SnCl_4$ vapour for the production of the main system, and Loomis and Watson used an arc at reduced pressure for their system. In absorption by Sharma.

References. F. C. Connelly, *Proc. Phys. Soc.*, **45**, 780. (1933)†.
F. W. Loomis and T. F. Watson, *P.R.*, **45**, 805. (1934).
D. Sharma, *Proc. Nat. Acad. Sci. India*, **A14**, 133. (1944).

The strongest system, A, lies in the violet and near ultra-violet, and two doubtful weaker systems B and C are also in the violet. Loomis and Watson's system is a little further to the ultra-violet.

Main System A, λλ4488–3072

Appearance. Degraded to red.
Transition. $^1\Sigma \rightarrow {}^1\Sigma$, ground state.

The strong bands only are listed. Intensities on scale of 8.

λ	I	v', v''	λ	I	v', v''
3691·4	5	0, 3	3388·3	6	0, 0
3585·4	7	0, 2	3323·4	7	1, 0
3484·5	8	0, 1	3262·4	6	2, 0
3415·8	5	1, 1	3205·8	4	3, 0

Systems B and C

Degraded to red. Strong bands :—

System B			System C		
λ	I	v', v''	λ	I	v', v''
4217·7	3	0, 2	4411·4	3	0, 2
4079·1	3	0, 1	4302·9	3	1, 2
3978·7	2	1, 1	4262·3	3	0, 1

Loomis and Watson's System

Appearance. Degraded to red.
Transition. To ground state.

Strong bands only are listed. Intensities I_e and I_a on a scale of 8 for emission and 10 for absorption, respectively.

λ	I_e	I_a	v', v''	λ	I_e	I_a	v', v''	λ	I_e	I_a	v', v''
3043·6	6		2, 6	2740·1	6	4	3, 2	2560·0	3	10	5, 0
2990·4	8		0, 4	2716·9	7	8	2, 1	2529·9	3	10	6, 0
2947·7	6		1, 4	2680·8	6	9	3, 1	2500·4	2	10	7, 0
2921·7	8	2	0, 3	2658·1	6	2	2, 0	2472·3	2	10	8, 0
2814·8	8	5	1, 2	2646·9	6	9	4, 1	2445·0	1	9	9, 0

Note added in proof. B. Eisler and R. F. Barrow (*Proc. Phys. Soc.*, **62**, 740 (1949)†) have extended Loomis and Watson's system and shown that v' should be raised one unit. All systems have been obtained in absorption. There may be a new system of bands, degraded to the red, λλ2132, 2117, 2102, 2084, 2073, 2069, 2054, 2050, 2037.

SnS

Three systems have been obtained in absorption, and two of these, B and C, have been observed by Barrow in a discharge tube.

References. G. D. Rochester, *P.R.S.*, **150**, 668. (1935)†.
D. Sharma, *Proc. Nat. Acad. Sci. India*, A14, 217. (1945)†.

System A, λλ4709–4183

Strongest bands, degraded to red, λλ4505·3, 4430·7, 4337·7, 4248·4, 4183·2.

System B, λλ4033–3198

Degraded to the red. Strongest bands, λλ3865·3, 3728·2, 3662·8, 3599·3, 3557·1, 3496·6, 3418·8, 3381·6.

System C, λλ3325–2700

Degraded to red. Strongest bands (intensity 10) from Sharma, 3163·9 (2, 4), 3116·8 (2, 3), 3089·1 (3, 3), 3062·4 (4, 3), 2992·6 (5, 2), 2967·7 (6, 2), 2902·1 (7, 1), 2879·2 (8, 1), 2735·8 (13, 0), 2715·9 (14, 0).

SnSe

Three band systems, A, B, and C, have been obtained in absorption by Walker *et al.*, and system C and a possible fourth system D have been obtained by Barrow and Vago in emission in a high-current-density discharge through the vapours of Sn and Se. The bands of all systems are degraded to the red. Many of the heads are rather diffuse because of isotope splitting.

References. J. W. Walker, J. W. Straley and A. W. Smith, *P.R.*, **53**, 140. (1938).
R. F. Barrow and E. E. Vago, *Proc. Phys. Soc.*, **55**, 326. (1943)†.
D. Sharma, *Proc. Nat. Acad. Sci. India*, A14, 224. (1945).

System A

Strongest bands : λλ5392·8 (1, 3), 5330·0 (2, 3), 5238·6 (2, 2).

System B

Strongest bands, in absorption :—

λ	I	v′, v″	λ	I	v′, v″
4734·5	7	1, 5	4572·8	10	0, 2
4664·4	10	1, 4	4504·8	10	0, 1
4646·1	6	0, 3	4396·3	10	0, 0
4595·2	7	1, 3			

System C

Strongest bands in emission, with our estimates of intensity from published spectrogram :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3963·7	7	0, 7	3770·9	9	0, 3	3620·2	8	2, 1
3914·1	8	0, 6	3739·2	10	1, 3	3591·6	10	3, 1
3865·1	8	0, 5	3694·1	9	1, 2	3563·5	9	4, 1
3817·7	9	0, 4	3664·0	9	2, 3	3536·3	8	5, 1

SnSe (*contd.*)

SYSTEM D

The following bands have been observed in emission: λλ3434·7, 3397·3, 3374·9, 3359·8, 3339·0, 3317·8, 3297·0, 3282·2, 3267·8, 3247·4, 3242·2, 3227·8, 3214·0, 3203·4, 3189·7, 3157·6, 3119·3, 3102·2 ; no intensities are available.

SnTe

Five systems of bands, A, B, C, D, and E, all degraded to the red, have been observed in absorption by Barrow and Vago, and two of these systems, D and E (referred to as A and B in Barrow's first paper), have been obtained in emission in an uncondensed discharge through a mixture of Sn, Te and Al vapours. Sharma has recently reported four more systems in absorption.

References. R. F. Barrow, *Proc. Phys. Soc.*, **52**, 380. (1940)†.
R. F. Barrow and E. E. Vago, *Proc. Phys. Soc.*, **56**, 78. (1944)†.
D. Sharma, *Proc. Nat. Acad. Sci. India*, A14, 232. (1945).

No intensity estimates are available, but the following bands appear prominently in the published spectrograms.

SYSTEM A

λ	v′, v″	λ	v′, v″	λ	v′, v″
6236·2	0, 3	5916·0	2, 1	5653·7	5, 0
6167·6	1, 3	5854·8	3, 1	5598·8	6, 0
6071·6	1, 2	5795·8	4, 1	5545·5	7, 0
6007·3	2, 2	5710·1	4, 0		

SYSTEM B

λ	v′, v″	λ	v′, v″	λ	v′, v″
5165·7	0, 4	4975·6	1, 2	4807·7	3, 1
5098·6	0, 3	4968·5	0, 1	4798·5	2, 0
5040·0	1, 3	4912·8	1, 1	4748·5	3, 0
5033·0	0, 2	4859·2	2, 1	4699·4	4, 0

SYSTEM C

λ	v′, v″	λ	v′, v″	λ	v′, v″
4738·8	1, 2	4580·0	2, 0	4493·1	4, 0
4672·0	0, 0	4546·1	4, 1	4451·1	5, 0
4634·7	2, 1	4535·8	3, 0	4410·5	6, 0
4589·6	3, 1				

SYSTEM D

λ	v′, v″	λ	v′, v″	λ	v′, v″
4189·5	0, 6	4058·8	0, 3	3893·3	3, 1
4145·3	0, 5	3988·5	1, 2	3854·0	3, 0
4101·3	0, 4	3920·3	2, 1	3827·9	4, 0

SYSTEM E

λ	v′, v″
3765·0	0, 4
3728·9	0, 3
3693·9	0, 2

SnTe (*contd.*)

Sharma's systems lie in the regions

F. λλ3666–3456
G. λλ3512–3298
H. λλ3309–3165
K. λλ2400–2100

Each consists of a fairly large number of closely-spaced bands, all degraded to the red.

SrBr

There are two systems attributed to SrBr, in the red and in the violet.

RED SYSTEM

Occurrence. In absorption and when strontium bromide is introduced into a flame. They do not appear strongly in an arc.

Appearance. Close marked sequences ; the bands appear to be degraded to shorter wave-lengths under low dispersion.

Transition. Probably $^2\Pi \rightarrow {}^2\Sigma$, ground state.

References. K. Hedfeld, *Z.P.*, **68**, 610. (1931).
O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).

The following list of measurements is compiled from the above sources. Intensities I_a and I_f are for absorption and emission in a flame respectively.

λ	I_a	I_f	Sequence
6924	0		
6800·2	10		
6763·6		0	0, 1 i
6666·7	10	10	0, 0 i
6605·4		0	0, 1 ii
6572·4		0	1, 0 i
6513·0	5	10	0, 0 ii
6422·8		0	1, 0 ii

VIOLET SYSTEM

Occurrence. In absorption and in a flame.

Appearance. Close sequences which appear to be degraded to longer wave-lengths with small dispersion.

References. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928).
C. M. Olmsted, *Z. wiss., Photogr.*, **4**, 255. (1906).

The following measurements are by Walters and Barratt. Intensities I_a and I_f are for absorption and emission in a flame, the latter being by Olmsted.

λ	I_a	I_f	λ	I_a	I_f
4186	0	1	4053	10	6
4146	4	3	4019	2	3
4129	1	2	3992	0	1
4108	9	6	3945	5	
4090	3	3	3909	5	
4073	2	3			

SrCl

Occurrence. When strontium chloride is introduced into an arc or flame. Also in absorption.

References. K. Hedfeld, *Z.P.*, **68**, 610. (1931)†.
A. E. Parker, *P.R.*, **47**, 349. (1935).

There are two strong systems, in the red and violet respectively. Parker also reports some weaker bands in the red and orange.

Red System, λλ6752–6232

Appearance. Degraded to violet. Close sequences.
Transition. Perhaps A $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Heads of strong sequences :—

λ	*I*	Sequence *
6755·6	3	0, 1 P_1
6744·7	5	Q_1
6619·9	5	0, 0 P_1
6613·7	10	Q_1
6482·9	4	1, 0 Q_1 and 0, 1 Q_2
6362·4	5	0, 0 P_2
6358·7	10	Q_2
6239·3	2	1, 0 Q_2

* The vibrational analyses made by Hedfeld and by Parker do not correspond exactly.

Violet System, λλ4136–3852

Appearance. Degraded to red.
Transition. Perhaps B $^2\Pi \rightarrow {}^2\Sigma$, ground state.

No intensities given. The following are the Q heads of sequences, the R heads, which are presumably weaker, lie about 1 A to the violet :—

λ						
4009·4	Q_1 head of (1, 2) band, the first observed member of the (0, 1) sequence.					
3983·4	Q_2 head of (1, 2) band.					
*3961·6	Q_1 head of (0, 0) band and sequence.					
3937·1	Q_2	,,	,,	,,	,,	,,
3918.3	Q_1	,,	(1, 0)	,,	,,	,,
3894·0	Q_2	,,	,,	,,	,,	,,

* Strongest head.

Weaker Bands. These may be due to CaCl.

Heads of sequences :—

λ	Degraded
6462·0	V
6184·8	V
6070·3	R
6068·1	R
5934·1	R

SrF

Seven systems have been observed in absorption by heated SrF_2 vapour by Fowler, and three of these, the A system in the red, the B system in the yellow, and the C system, are well known in emission when SrF_2 is introduced into a carbon arc or flame.

References. S. Datta, *P.R.S.*, **99**, 436. (1921)†.
R. C. Johnson, *P.R.S.*, **122**, 161. (1929).
A. Harvey, *P.R.S.*, **133**, 336. (1931)†.
C. A. Fowler, *P.R.*, **59**, 645. (1941)†.

RED SYSTEM, λλ6870–6283

A $^2\Pi \rightarrow {}^2\Sigma$, ground state. Marked sequences. Appearance best shown by Datta's photographs.

Strongest heads of sequences :—

λ		I	Sequence
6655·6	V	7	0, 0 P_{12}
6632·7	V	10	0, 0 Q_{12}
6527·6	V	7	0, 0 P_2
6512·0	V	10	0, 0 Q_2
6419·0	V	8	1, 0
6394·7	R		
6306·1	V	8	1, 0
6283·1	R		

YELLOW SYSTEM, λλ5852–5021

B $^2\Sigma \rightarrow {}^2\Sigma$, ground state. Degraded to red.

(0, 0) sequence R head λ 5779·5
,, ,, Q ,, 5772·0
(1, 0) sequence, evenly spaced bands between λ5622 and 5670.

C SYSTEM, λλ3795–3646

C $^2\Pi \rightarrow {}^2\Sigma$, ground state. Degraded to red. Heads of sequences at λλ3646·3 and 3712·4.

D SYSTEM, λλ3592–3345

D $^2\Sigma \rightarrow {}^2\Sigma$, ground state. Degraded to shorter wave-lengths. Strongest bands in absorption (calculated from Fowler's formula) :—

λ	I	v', v''
3529·8	9	0, 0
3522·9	10	1, 1
3517·1	8	2, 2
3457·2	7	2, 1
3451·6	7	3, 2

E SYSTEM, λλ3218–3052

E $^2\Pi \rightarrow {}^2\Sigma$, ground state. Degraded to shorter wave-lengths. Strongest bands in absorption :—

SrF (*contd.*)

λ	I	v', v''
3218·2	5	0, 1
3167·6	10	0, 0
3112·6	7	1, 0
3106·4	6	2, 1

F SYSTEM, $\lambda\lambda$3069–2916

F $^2\Sigma \rightarrow {}^2\Sigma$, ground state. Degraded to shorter wave-lengths. Strongest bands in absorption :—

λ	I	v', v''
3088·3	6	0, 1
3041·5	8	0, 0
2987·8	10	1, 0
2978·1	7	2, 1
2929·6	7	3, 1

G SYSTEM, $\lambda\lambda$2915–2775

G $^2\Pi \rightarrow {}^2\Sigma$, ground state. Degraded to shorter wave-lengths. Strongest bands in absorption :—

λ	I	v', v''
2873·2	10	0, 0
2826·7	8	1, 0
2821·0	5	2, 1
2782·0	6	2, 0

SrH

Reference. W. W. Watson and W. R. Fredrickson, *P.R.*, 39, 765. (1932).

7508 A. SYSTEM, $^2\Pi \rightarrow {}^2\Sigma$, GROUND STATE

Bands degraded to the violet. Obtained from strontium arc in hydrogen.

v', v''	Heads	
0, 0	7508	P_1
	7505	$^PQ_{12}$
	7348·0	$^QP_{21}$
	7346·7	Q_2

7020 A. SYSTEM, $^2\Sigma \rightarrow {}^2\Sigma$, GROUND STATE

Bands degraded to the violet. Obtained in strontium arc in hydrogen.

v', v''	Heads	
0, 0	7018·1	P_1
	6984·7	P_2

OTHER SYSTEMS ?

Watson and Fredrickson note that in their experiments a dense grouping of lines appeared in the yellow-green and small groups at around 5800 A.

SrI

Band systems have been observed in the red and violet by Walters and Barratt, who also report three faint bands in the ultra-violet.

References. O. H. Walters and S. Barratt, *P.R.S.*, **118**, 120. (1928)†.
C. M. Olmsted, *Z. wiss. Photogr.*, **4**, 255. (1906).

SrI (*contd.*)

RED SYSTEM

Occurrence. In absorption. Olmsted also speaks of bands in the orange in a flame source; these may be the same.

Appearance. Degraded to the violet.

The following measurements are by Walters and Barratt :—

λ	I	λ	I
7094·0	2	6767·8	10
7011·0	10	6691·5	8
6930·2	10	6662·3	8
6847·7	10	6177·3	4

VIOLET SYSTEM

Occurrence. In absorption, when strontium iodide is introduced into a flame, and probably in arc sources.

Appearance. Degraded to the red. Marked close sequences. The following measurements of the heads of the sequences are by Walters and Barratt. Intensities I_a and I_f are for absorption and emission in a flame respectively, the latter being by Olmsted.

λ	I_a	I_f	λ	I_a	I_f
4482	0	4	4339	2	4
4447	4	5	4307	6	6
4412	10	6	4276	1	2
4381	1	4			

ULTRA-VIOLET

Three weak bands λλ3439, 3406, and 3378, degraded to shorter wave-lengths, were observed in absorption.

SrO

Occurrence. When strontium salts are introduced into a carbon arc burning in air or into a flame.

Appearance. Degraded to red. Two systems, in the blue, and in the ultra-violet.

Reference. P. C. Mahanti, *P.R.*, **42**, 609. (1932)†.

Only the strong bands listed by Mahanti are given below. The intensities are on a scale of 6.

BLUE SYSTEM

λ	I	v', v''	λ	I	v', v''
4692·7	5	2, 7	4399·6	6	0, 3
4672·6	4	1, 6	4302·7	4	1, 3
4652·4	3	0, 5	4281·0	5	0, 2
4564·8	5	2, 6	4189·1	4	1, 2
4544·1	5	1, 5	4167·2	5	0, 1
4523·3	4	0, 4	4058·0	3	0, 0
4463·3	4	3, 6	3975·4	3	1, 0
4420·9	4	1, 4	3897·1	3	2, 0

SrO (*contd.*)

ULTRA-VIOLET SYSTEM

λ	I	v′, v″
3586·9	3	0, 1
3525·4	3	1, 1
3503·8	6	0, 0
3445·2	4	1, 0
3389·8	4	2, 0
3337·5	3	3, 0

INFRA-RED SYSTEM

Appearance. Degraded to the red.

References. K. Mahla, *Z.P.*, **81**, 625. (1933)†.

G. Almkvist and A. Lagerqvist, *Nature, Lond.*, **164**, 665. (1949)

Almkvist and Lagerqvist give the analysis,

λ	v′, v″	λ	v′, v″
10437·1	1, 3	8722·5	2, 1
10426·2	0, 2	8700·0	1, 0
9776·1	0, 1	8257·8	2, 0
9195·8	0, 0		

Mahla also gives heads at λλ7852·8 and 7484·3.

ORANGE-RED SYSTEM, 7000–5300 A.

There is a strong patch of emission around 6000 A. which occurs in flames, arcs and heavy-current discharges containing SrO. The assignment to SrO is probable, but not certain (Mahanti attributes them to Sr_2). The band around 6000 shows weak heads, degraded to the violet, for which Dr. R. F. Barrow has supplied the following measurements: λλ6114·2, 6111·9, 6109·9, 6107·5, 6101·3, 6096·5, 6090·2, 6085·1, 6077·2. There is a similar band around 6200–6900 with the following heads: λλ6884·5, 6875·6, 6867·9, 6861·4.

TaO

Reference. C. C. Kiess and E. Z. Stowell, *Nat. Bur. Stand. J. Res.*, **12**, 459. (1934).

In studying the line spectrum of tantalum, as obtained from an arc between metallic poles, Kiess and Stowell record a band spectrum probably due to TaO. The bands are degraded to longer wave-lengths; the following are the strongest bands:—

λ	I	λ	I	λ	I
5567·0	4	4679·5	3	4006·2	4
5385·2	3?	4651·9	3	3896·4	4
4901·6	3?	4154·4	7?	3747·2	4
4810·4	4	4092·1	3?	3625·7	4

Further bands were observed in the infra-red.

Te_2

MAIN SYSTEM

Occurrence. Absorption by tellurium vapour, fluorescence, and emission (presumably in discharge tubes).

Appearance. Degraded to the red. An extensive system consisting of a large number of bands.

Te_2 *(contd.)*

References. B. Rosen, *Z.P.*, **43**, 69. (1927).
E. Olsson, *Z.P.*, **95**, 215. (1935).

The following measurements of the strong bands are by Olsson, with his vibrational quantum numbers. The intensities are from Rosen and are for absorption. The band heads are complex because of the isotope effect. Olsson's measurements are for the strongest head, $Te^{128}Te^{128} + Te^{130}Te^{126}$. Rosen's measurements are systematically lower than Olsson's by an amount increasing from zero at the red end of the system to 5 A at the violet end, this probably being largely due to the isotope effect.

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
4849·0	3	1, 7	4448·8	3	5, 2	4211·8	3	10, 0
4793·6	3	1, 6	4435·7	3	7, 3	4202·9	4	12, 1
4740·7	3	1, 5	4418·3	3	6, 2	4185·7	3	11, 0
4703·5	3	2, 5	4388·4	3	7, 2	4159·6	4	12, 0
4686·7	3	4, 6	4369·4	3	6, 1	4134·5	4	13, 0
4666·8	3	3, 5	4358·9	4	8, 2	4110·0	5	14, 0
4649·4	3	2, 4	4341·3	3	7 1	4082·8	5	15, 0
4617·2	3	6, 6	4330·4	4	9, 2	4060·6	5	16, 0
4581·0	4	4, 4	4312·5	3	8, 1	4040·2	5	17, 0
4564·9	3	6, 5	4302·2	4	10, 2	4018·2	5	18, 0
4548·1	4	5, 4	4284·5	4	9, 1	3996·8	5	19, 0
4530·0	4	4, 3	4256·8	4	10, 1	3976·0	5	20, 0
4498·0	4	5, 3	4238·1	3	9, 0	3956·0	4	21, 0
4466·4	3	6, 3	4230·2	4	11, 1	3913·5	4	22, 0

OTHER SYSTEMS

References. M. Désirant and A. Minne, *C.R. Acad. Sci. Paris*, **202**, 1272. (1936).
Choong Shin-Piaw, *C.R. Acad. Sci. Paris*, **203**, 239. (1936); and *Ann. Phys. Paris*, **10**, 173. (1938).
R. Migeotte, *Mem. Soc. Roy. Sci. Liége*, **5**, 1. (1942).

Désirant and Minne record bands in the visible in a high-frequency discharge, analysed into two systems with origins of the (0, 0) bands at $\nu = 18{,}900$ and 16,370.

Choong Shin-Piaw has studied the spectrum in the ultra-violet and gives a formula for bands in the region λλ2495–1975. Migeotte has arranged absorption bands in this region into four systems.

$TeBr_2$

Diffuse bands, degraded to the red, in the region λλ6500–5300 have been observed in absorption.

Reference. M. Wehrli, *Helvetica Phys. Acta*, **9**, 208. (1936)†.

Strongest bands :—

λ	I
6037	6
5957	7
5888	8
5816	9
5744	9
5676	8

$TeCl_2$

Visible System

Diffuse bands, degraded to the red, in the region λλ6400–4725 have been observed in absorption.

Reference. M. Wehrli, *Helvetica Phys. Acta.*, **9**, 208. (1936)†.

Strongest bands :—

λ	I	λ	I
5758·6	3	5443·4	7
5720·0	2	5353·6	6
5656·1	3	5267·5	5
5634·3	3	5183·5	4
5536·4	5	5103	4

Ultra-violet System

Bands 2050–2300 A. in absorption. Degraded to shorter wave-lengths.

Reference. P. Müller and M. Wehrli, *Helvetica Phys. Acta.*, **15**, 307. (1942).

Strongest bands : λλ2079·6, 2084·6, 2105·4, 2111·9, 2118·6, 2138·6.

TeO

Occurrence. Discharge through tellurium vapour and oxygen in heated silica tube. Also in absorption.

Appearance. Degraded to red.

Reference. Choong Shin-Piaw, *Ann. Phys. Paris*, **10**, 173. (1938)†.

Strong bands :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3818·8	10	0, 4	3607·0	8	0, 2	3463·8	7	1, 1
3767·2	5	1, 4	3560·6	8	1, 2	3422·2	7	2, 1
3710·0	10	0, 3	3517·2	6	2, 2	3382·9	6	3, 1
3661·3	8	1, 3	3507·5	5	0, 1	3345·6	6	4, 1

TeO_2

Reference. As TeO.

A complex system of diffuse bands has been observed in absorption 4000–3200 A. The following are the strongest bands : λλ3960·1, 3942·7, 3922·8, 3891·1, 3799·9, 3772·9, 3771·0, 3706·4, 3617·8, 3590·8.

Note added in proof. J. Duchesne and B. Rosen (*J. Chem. Phys.*, **15**, 631 (1947)) have listed about 88 absorption bands between 4555 and 3026 A. Their values, for band maxima, show practically no agreement with those above. They also list 12 bands λλ2650–2450.

TiCl

Occurrence. Discharge tubes (including high-frequency discharge) containing flowing titanium chloride, $TiCl_4$, vapour.

Appearance. Degraded to shorter wave-lengths. A strong close sequence with head at 4192 A.

Reference. K. R. More and A. H. Parker, *P.R.*, **52**, 1150. (1937).

TiCl (*contd.*)

In the following table all the observed heads of the (0, 0) band and the strongest (second) head of the other strong bands are given :—

λ	I	v′, v″
4199·5	1	0, 0
4192·7	10	
4189·1	4	
4188·0	8	
4184·5	6	
4181·8	5	
4183·1	9	1, 1
4172·2	9	2, 2
4160·3	6	3, 3
4106·9	3	1, 0

There are also weaker bands in the regions 4050–4000 A., 3935–3840 A., 3750–3720 A., but no measurements are available.

TiO

Three strong systems, in the red, the orange and the blue-green, have been attributed to this molecule. See Plate 8.

Occurrence. In arcs and furnaces containing titanium dioxide and in discharge tubes containing titanium chloride and oxygen. The bands are a prominent feature of the spectra of M-type stars.

Red System, γ

Appearance. Degraded to longer wave-lengths. The bands have rather widely-spaced triple heads, but the appearance is confused by overlapping.

Transition. A $^3\Sigma \rightarrow$ X $^3\Pi$, probably ground state.

Reference. F. Lowater, *Proc. Phys. Soc.*, 41, 557. (1929)†.

The following are the strong heads as listed by Lowater. Intensities have been reduced to a scale of 10.

λ	I	v′, v″	λ	I	v′, v″
7948·6	7	4, 5 Q_b	7197·7	7	1, 1 R_c, 2, 2 R_a
7907·3	5	4, 5 Q_a, 3, 4 R_c	7159·0	5	1, 1 R_b
7861·0	5	3, 4 R_b	7125·6	10	0, 0 R_c, 1, 1 R_a
7828·0	8	2, 3 R_c, 3, 4 Q_a	7087·9	9	0, 0 R_b
7820·1	7	3, 4 R_a	7054·5	7	0, 0 R_a
7705·2	7	1, 2 R_b	6852·3	5	4, 3 R_a
7672·1	8	0, 1 R_c, 1, 2 Q_a	6719·3	5	2, 1 R_a, 1, 0 Q_c
7666·4	5	1, 2 R_a	6714·4	5	1, 0 R_c
7628·1	7	0, 1 R_b	6681·1	5	1, 0 R_b
7589·6	7	0, 1 R_a	6651·5	4	1, 0 R_a
7269·0	5	2, 2 R_c, 3, 3 R_a	6215·2	5	6, 3 Q_c
7219·4	5	1, 1 Q_c			

Orange System, β

Appearance. Degraded to the red. A single sequence of double-headed bands.

Transition. Uncertain. The appearance is suggestive of a singlet system, but efforts have been made to relate it to the $^3\Pi$ ground state.

TiO (*contd.*)

Reference. F. Lowater, *Proc. Phys. Soc.*, **41**, 557. (1929)†.

The following are the strongest heads :—

λ	I	v', v''
5694·4	3	3, 3 R
5661·6	6	2, 2 R
5629·3	6	1, 1 R
5603·8	3	0, 0 Q
5597·8	7	0, 0 R

Blue-Green System, α

Appearance. Degraded to the red ; close triple-headed bands forming fairly obvious sequences.

Transition. $^3\Pi \rightarrow {}^3\Pi$, ground state.

References. A. Fowler, *P.R.S.*, **79**, 509. (1907)†.
A. Christy, *P.R.*, **33**, 701. (1929).

First heads of strong bands :—

λ	I	v', v''	λ	I	v', v''	λ	I	v', v''
6214·9	8	2, 5	5448·3	7	0, 1	4848·0	3	4, 2
6159·1	10	1, 4	5240·5	5	1, 1	4804·3	5	3, 1
5861·7	4	2, 4	5166·9	7	0, 0	4761·2	5	2, 0
5810·0	4	1, 3	5050·3	3	3, 2	4626·1	4	4, 1
5758·5	4	0, 2	5002·7	3	2, 1	4584·1	3	3, 0
5497·0	5	1, 2	4954·5	6	1, 0	4462·1	3	4, 0

TlBr

Main System

Occurrence. In uncondensed discharge ; also in absorption.

Appearance. Degraded to red.

Transition. (Hund's case *c*) 1 $\rightarrow {}^1\Sigma$, ground state.

References. K. Butkow, *Z.P.*, **58**, 232. (1929)†.
H. G. Howell and N. Coulson, *Proc. Phys. Soc.*, **53**, 706. (1941)†.

Strongest bands (for isotope $TlBr^{79}$) from Butkow. Intensities in absorption.

λ	I	v', v''	λ	I	v', v''	λ	I	v', v''
3556·5	3	1, 6	3486·4	7	1, 3	3440·9	6	1, 1
3532·9	4	1, 5	3475·3	8	0, 2	3429·6	10	0, 0
3509·7	5	1, 4	3463·6	8	1, 2	3418·2	9	1, 0
3498·4	5	0, 3	3452·4	9	0, 1	3408·2	6	2, 0

3950 A. System

Occurrence. Uncondensed discharge through TlBr vapour.

Appearance. Degraded to red.

Transition. From a highly excited state to upper level of main system.

Reference. H. G. Howell and N. Coulson, *Proc. Phys. Soc.*, **53**, 706. (1941)†.

Strong bands :—

λ	I	v', v''
3973·8	6	0, 2
3960·2	8	0, 1
3945·2	10	0, 0
3933·7	8	1, 0

TlBr (*contd.*)

Note added in proof. P. T. Rao (*Indian J. Phys.*, **23**, 265 (1949)) suggests that there may be a new system 3980–3800 A. and that the v' numbering for some bands of the main system may be in error.

TlCl

In absorption thallium chloride vapour shows a strong band system between 3575 and 3176 A. and two strong narrow regions of continuum centered at 3110 and 2520 A. The band system has been observed in absorption as an impurity in other substances, especially in cadmium. It is also obtained in emission in a discharge tube (including a high-frequency discharge) through TlCl vapour. Miescher has also reported another band system in the violet in emission in a discharge tube.

References. H. G. Howell and N. Coulson, *P.R.S.*, **166**, 238. (1938)†.
E. Miescher, *Helv. Phys. Acta.*, **14**, 148. (1941)†.
P. T. Rao, *Curr. Sci.*, **18**, 42. (1949).

MAIN SYSTEM, λλ3575–3176

Appearance. Degraded to the red. Strong (0, 0) sequence. The bands show isotope effect.

The following are the heads of the more abundant isotope $TlCl^{35}$ for the strong bands as obtained in emission by Howell and Coulson :—

λ	I	v′, v″	λ	I	v′, v″	λ	I	v′, v″
3372·0	2	3, 7	3299·7	7	2, 4	*3240·6	9	2, 2
3360·4	1	2, 6	3289·6	8	1, 3	*3230·4	10	1, 1
3341·4	2	3, 6	3270·0	7	2, 3	*3220·9	10	0, 0
3329·9	2	2, 5	*3263·6	2	4, 4	3201·3	2	1, 0
3323·5	3	4, 6	3259·9	8	1, 2	*3193·4	1	3, 1
3319·6	3	1, 4	*3250·8	7	0, 1	*3182·6	2	2, 0

* Relatively strong in absorption.

VIOLET SYSTEM

Appearance. A complex system of bands, strongest in the region 4120–4050 A., with heads degraded in either direction.

Strongest heads from Miescher ; letters R, V and M denote degraded to red, violet, or maximum of headless structure :—

λ		I	λ		I	λ		I	λ		I
4244·6	R	6	4108·3	R	10	4060	M	10	4021	M	6
4223·6	R	8	4096·8	R	8	4051	M	8	4015·2	R	5
4218·0	R	6	4088·7	V	6	4045·6	M	9	3991·9	R	4
4210·7	V	6	4086·6	R	8	4038·4	R	7	3972	M	4
4182	V	5	4085·9	V	10	4025	M	5	3947·5	R	4

TlF

Three systems have been obtained in absorption in thallium fluoride vapour, and the first two of these have been observed in emission in a high-frequency discharge.

Reference. H. G. Howell, *P.R.S.*, **160**, 242. (1937)†.

SYSTEM $^3 1 \rightarrow {}^1\Sigma$, λλ3105–2809

Bands degraded in either direction. The following are the strongest heads, with the direction of degradation indicated by R (red) and V (violet).

TlF (*contd.*)

λ	I	v′ v″	λ	I	v′, v″	λ	I	v′, v″
2924·7 V	5	1, 3	2882·0 V	6	0, 1	2843·5 V	10	0, 0
2921·3 V	5	0, 2	2852·2 V	9	2, 2	2818·4 R	5	3, 2
2886·0 V	6	1, 2	2848·0 V	10	1, 1	2810·6 V	7	1, 0

SYSTEM $^3 0^+ \rightarrow {}^1\Sigma^+$, λλ2808–2668

Degraded to red. Close double-headed bands :—

λ	I	v′, v″	λ	I	v′, v″
2759·7	7	1, 2	2724·9	10	1, 1
2748·1	6	0, 1	2713·7	10	0, 0
2737·1	9	2, 2	2690·8	3	1, 0

SYSTEM $^1\Pi \rightarrow {}^1\Sigma$, λλ2347–2198

Degraded to the red :—

λ	I	v′, v″	λ	I	v′, v″
2250·4	4	1, 3	2221·0	9	0, 1
2244·3	5	0, 2	2203·9	8	1, 1
2227·0	8	1, 2	2198·0	10	0, 0

TlH

Several band systems were observed by Grundström and Valberg when thallium metal was heated with hydrogen in a furnace and when an arc between thallium and copper poles was run in hydrogen at about 500 mm. pressure. The bands are not yet completely systematised.

Reference. B. Grundström and P. Valberg, *Z.P.*, **108**, 326. (1938)†.

B → A SYSTEM

v′, v″	Origins
0, 0	5706·2
0, 1	6180·9

C → A SYSTEM. Degraded red.

v′, v″	Origins	R Heads
0, 1	5903·8	5895·2
1, 2	5914·4	5911·7
0, 2	6394·7	6382·9
0, 3	6952·8	6935·9

D → A SYSTEM. Degraded red.

v′, v″	Origins	R Heads
0, 1	5742·7	5739·2
1, 2	5772·3	—
0, 2	6206	—
1, 3	6223·2	6220·2
0, 3	6730·6	6725·0
1, 4	6729	—
0, 4	7327	7320

TlH (*contd.*)

E → A System. Degraded red.

v', v''	Origins	R Heads
0, 2	6058·6	6055·2
1, 3	6062·4	—
0, 3	6557·4	6553·2

TlI

Occurrence. In absorption by thallium iodide vapour.
Appearance. Diffuse headless bands.
Reference. K. Butkow, *Z.P.*, **58,** 232. (1929)†.

The following are the bands as listed by Butkow. No intensities are available, but from the reproduction it appears that the shorter wave-length bands are the stronger.

λλ3808, 3836, 3896, 3933, 3967, 4000, 4030, 4062, 4092, 4120, 4152, 4181 and 4211.

Note added in proof. P. T. Rao and K. R. Rao (*Indian J. Phys.*, 23, 185 (1949)†) have obtained the system in emission in a high-frequency discharge. They have made a vibrational analysis and suggest that the transition is $^3\Pi_1 \rightarrow {}^1\Sigma^+$. Bands in the violet are degraded to the red. Others are headless or diffuse. Of about 200 bands between 5300 and 3800 listed in this complex system, the following are given as strongest, λλ4620·8, 4591·3, 4557·1, 4511·6, 4477·9, 4422·6, 4342·6, 4315·9, 4269·7, 4213·3, 4113·2, 4088·8, 3900·8 (1, 2) and 3877·9 (0, 0).

There is also a weaker system of 25 bands 3680–3600 A.

VO

Occurrence. In the flame surrounding arc containing vanadium metal or oxide.
Appearance. Degraded to red. Double-headed, separation between R and Q heads about 0·8 A.
Transition. Probably $^2\Delta \rightarrow {}^2\Delta$.
Reference. P. C. Mahanti, *Proc. Phys. Soc.*, **47,** 433. (1935)†.

R heads of strong bands :—

λ	I	v', v''
6532·8	6	1, 3
6477·8	6	0, 2
6086·4	8	0, 1
5736·7	10	0, 0
5517·3	5	2, 1
5469·3	9	1, 0

WO

Occurrence. High-tension arc between tungsten electrodes in air.
Appearance. A complex system of single-headed bands degraded to the red.

The following are rough measurements by Foster and Gaydon of the strong heads. The system has not been analysed and is attributed to WO on experimental evidence only.

WO (*contd.*)

λ	I	λ	I	λ	
5396	3	4709·4	10	4414	5
5338	3	4609	8	4395	4
5210	5	4590·5	8	4338·5	5
4932	3	4562	4	4313	4
4903	3	4523	5	4284	4
4824	6	4473·5	5	4271·0	4
4806	9	4460	5	4110·5	2

YO

Occurrence. In arc containing yttrium salts.

References. L. W. Johnson and R. C. Johnson, *P.R.S.*, 133, 207. (1931).
W. F. Meggers and J. A. Wheeler, *Bur. Stand. J. Res.*, 6, 239. (1931)†.

Orange System

Appearance. Degraded to the red. Long sequences.

Transition. $^2\Pi \rightarrow {}^2\Sigma$, ground state.

The following measurements of the strong heads at the beginnings of the main sequences are from Johnson and Johnson :—

λ	I	v′, v″	λ	I	v′, v″
5697·8	5	1, 0 i Q	5939·1	8	0, 0 i R
5713·9	6	2, 1 i Q	5956·4	7	1, 1 i R
5730·2	7	3, 2 i Q	5972·2	10	0, 0 i Q
5747·0	8	4, 3 i Q	5987·7	10	1, 1 i Q
5764·3	7	5, 4 i Q	6003·6	10	2, 2 i Q
5842·0	4	1, 0 ii Q	6096·8	8	0, 0 ii R
5858·9	5	2, 1 ii Q	6114·8	7	1, 1 ii R
5876·2	4	3, 2 ii Q	6132·1	10	0, 0 ii Q
5912·3	6	5, 4 ii Q	6148·4	10	1, 1 ii Q
5931·1	5	6, 5 ii Q	6165·1	10	2, 2 ii Q

Blue-Green System

Appearance. Degraded to the red. Close double-headed bands, separation about 0·8 A.

Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

The following measurements of the first heads of the strong bands are by Johnson and Johnson :—

λ	I	v′, v″
5077·9	4	2, 3
5049·7	5	1, 2
5024·2	6	0, 1
4841·9	7	1, 1
4817·4	10	0, 0
4649·2	9	1, 0

Zn_2

References. H. Hamada, *Phil. Mag.*, **12**, 50. (1931)†.
J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).

Hamada has studied the emission by zinc in a hollow cathode. The zinc lines, especially λλ2139 and 3076 are broadened and show patches of continua and flutings attributed to incipient formation of Zn_2 molecules.

Walter and Barratt observe a diffuse band in absorption at about 3050 A.

ZnBr

References. K. Wieland, *Helv. Phys. Acta.*, 2, 46. (1929).
J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).
E. Oeser, *Z.P.*, **95**, 699. (1935).
H. G. Howell, *P.R.S.*, **182**, 95. (1943).

VISIBLE SYSTEM λλ8470–3300

Occurrence. Low pressure discharges (including high-frequency) with $ZnBr_2$.
Appearance. Crowded bands degraded to the red on a continuum with pronounced intensity maximum at λ8300. In the short wave region, at about λ3800, the bands are very faint but a partial resolution into rotational lines can be seen.
Transition. Probably $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

ULTRA-VIOLET BANDS λλ3113–3028

Occurrence. A number of bands, degraded to the red, has been observed in this region by Walter and Barratt in absorption.
Transition. Probably $^2\Pi \rightarrow {}^2\Sigma$, ground state.

Strongest heads :—

λ	I	v′, v″
3110	4	0, 0
3102	2	
3071	4	0, 0
3068	3	
3064	2	

$ZnBr_2$

No bands due to $ZnBr_2$ are known. Emission bands previously ascribed to this molecule by Wieland are attributed to ZnBr. In absorption only continuous spectra have been observed (E. Oeser, *Z.P.*, **95**, 699 (1935)).

ZnCl

References. K. Wieland, *Helv. Phys. Acta.*, 2, 46. (1929).
J. M. Walter and S. Barratt, *P.R.S.*, **122**, 201. (1929).
S. D. Cornell, *P.R.*, **54**, 341. (1938).

VISIBLE SYSTEM λλ8650–3200

Occurrence. $ZnCl_2$ in low-pressure discharge tubes (Wieland).
Appearance. Crowded bands degraded to the red on a continuum with intensity maximum at λ8200. Around λ4000 the bands are faint but partially resolved into rotational lines.
Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

ZnCl (*contd.*)

λλ2993–2903 SYSTEM

Occurrence. Observed by Cornell in a high-frequency discharge, and by Walter and Barratt in absorption.

Cornell apparently observed strong sequences (degraded to longer wave-lengths) at λλ2976·2 and 2942·6 and a weaker sequence at λ2910·0.

The following are the strongest absorption bands (intensities in brackets): λλ2956 (8), 2943 (5), 2934 (10), 2923 (5) and 2911 (2).

λ2074·4

A single sequence of bands degraded to the red observed by Cornell in a high-frequency discharge.

ZnF

λλ2700–2588 SYSTEM

Occurrence. In absorption.

Appearance. Degraded to the red.

Reference. G. D. Rochester and E. Olsson, *Z.P.*, **114**, 495. (1939).

Heads of the R branches :—

2703·2, 2676·3, 2673·1, 2660·0, 2634·3, 2630·0, 2587·7.

ZnH

Reference. G. Stenvinkel, *Dissertation,* Stockholm. (1936).

4300 A. SYSTEM $^2\Pi \rightarrow {}^2\Sigma$, GROUND STATE

Bands with P and Q heads degraded to the violet, obtained with zinc arc in hydrogen at reduced pressure and in quartz discharge tube containing zinc vapour and hydrogen. See Plate 4.

v', v''	$^2\Pi_{\frac{1}{2}} \rightarrow {}^2\Sigma$ Origins	Heads (I) Q	P	v', v''	$^2\Pi_{\frac{3}{2}} \rightarrow {}^2\Sigma$ Origins	Heads (I) Q	P
0, 3	5223·0			0, 3	5131·5		
0, 2	4905·3			0, 2	4824·5		
0, 1	4578·6			0, 1	4523·9		
0, 0	4299·1	4301 (10)	4260 (8)	0, 0	4237·0	4240 (10)	4326 (5)
1, 1	4238·3			1, 1	4178·2		
1, 0	3985·6	3989 (3)		1, 0	3932·2	3935 (3)	
2, 0	3726·0			2, 0	3679·4		

ULTRA-VIOLET SYSTEM $^2\Sigma \rightarrow {}^2\Sigma$, GROUND STATE

An extensive system of bands degraded to the red.

Origins

v', v''	λ	v', v''	λ
0, 5	4703·1	4, 0	3219·3
0, 4	4520·0	5, 0	3132·7
0, 3	4310·9	6, 0	3054·1
1, 2	3934·0	7, 0	2981·8
1, 1	3731·7	8, 0	2916·1
2, 0	3418·3	9, 0	2855·7
3, 0	3314·3	10, 0	2800·7

ZnH$^+$

Reference. E. Bengtsson and B. Grundström, *Z.P.*, 57, 1. (1929).

2152 A. SYSTEM, $^1\Sigma \rightarrow {}^1\Sigma$

An extensive system of singlet bands degraded to the red. The system is obtained in zinc arc in hydrogen at low pressures. See Plate 5.

v', v''	R Heads
1, 0	2091·7
2, 1	2115·1
0, 0	2151·9
0, 1	2240·2
1, 2	2261·5
0, 2	2332·0
1, 3	2350·7
2, 4	2366·5

ZnI

References. A. Terenin, *Z.P.*, 44, 713. (1927).
K. Wieland, *Helv. Phys. Acta.*, 2, 46. (1929).
E. Oeser, *Z.P.*, 95, 699. (1935)†.
P. T. Rao and K. R. Rao, *Indian J. Phys.*, 20, 49. (1946)†.
C. Ramasastry, *Indian J. Phys.*, 22, 119 (1948)† and 23, 35. (1949).

VISIBLE SYSTEM λλ6140–3500

Occurrence. In low-pressure discharge-tubes (Wieland) and in fluorescence of ZnI_2 (Terenin, Oeser).

Appearance. This system, usually referred to as system B, consists of diffuse line-like bands on a continuum with pronounced intensity maximum at 6050 A. If the spectrum is obtained from ZnI_2 vapour excited in the presence of a large excess of an inert gas, it shows a simplified vibrational structure of bands degraded to the red (Wieland).

Transition. $^2\Sigma \rightarrow {}^2\Sigma$, ground state.

SYSTEM λλ3393–3258

Appearance. Degraded to shorter wave-lengths.

Transition. Probably $^2\Pi_{1/2} \rightarrow {}^2\Sigma$, ground state.

This system is sometimes referred to as system C. Heads of strongest sequences observed by Wieland using a discharge-tube containing ZnI_2 :—

λ	I	v', v''
3367·3	5	0, 2
3342·6	8	0, 1
3318·0	10	0, 0
3291·1	7	1, 0

SYSTEM λλ3277–3193

Appearance. Diffuse bands.

Transition. Probably $^2\Pi_{3/2} \rightarrow {}^2\Sigma$, ground state.

ZnI (*contd.*)

These bands are considered by Rao and Rao to form with system C the two components of a $^2\Pi \rightarrow {}^2\Sigma$ transition. They refer to them as system D. Strongest bands :—

λ	I	v', v''	λ	I	v', v''
3277·7	0	0, 0	3232·5	3	2, 0
3265·7	2		3215·0	3	4, 1
3262·5	3		3212·5	3	3, 0
3257·2	2	3, 2	3196·5	2	5, 1
3254·8	2	1, 0	3193·5	3	4, 0
3235·7	4	3, 1			

System λλ2990–2715

A large number of bands in this region have been observed by Ramasastry using a high-frequency discharge. He designates them system D_1. The bands are degraded to the red. Strongest bands :—
λ(I) ; 2989·0 (6), 2983·2 (5), 2971·4 (4), 2952·6 (4), 2946·4 (4), 2872·2 (4), 2823·9 (5), 2817·4 (4), 2815·7 (4), 2764·4 (4).

System λλ2450–2250

A weak system, degraded to the red, observed in a discharge-tube by Wieland. The system has been studied more extensively by Ramasastry who refers to it as system E. Strongest bands :—
λ(I) ; 2384·5 (4), 2376·8 (4), 2373·1 (4), 2369·4 (4), 2365·2 (4), 2357·8 (4), 2353·5 (5), 2341·9 (5), 2330·1 (3).

ZnS

Reference. P. K. Sen Gupta, *P.R.S.*, **143**, 438. (1933–4).

Continuous absorption from 2800 A. to shorter wave-lengths with maximum around 2300 A.

ZrF ?

Reference. M. Afaf, *Thesis Ph.D.*, London. (1949)†.

With an arc containing ZrF_4 Afaf obtained a complex band structure in the region 5100–4900 A. possibly due to ZrF. Strongest heads :—
λ(I) ; 4933·9 (4), 4933·4 (4), 4932·1 (5), 4926·9 (4), 4921·6 (5), 4920·2 (2), 4916·3 (3), 4914·8 (2), 4911·4 (2), 4906·2 (2).

ZrO

Occurrence. Zirconium oxide in arc.
References. F. Lowater, *Proc. Phys. Soc.*, **44**, 51. (1932)†.
F. Lowater, *Phil. Trans. Roy. Soc.*, **234A**, 355. (1935)†.

The following are the wave-lengths of the strongest heads of the three systems, degraded to the red, obtained by Lowater. The intensities have been reduced to a scale of 10.

ZrO (*contd.*)

α System, Blue

Transition. C $^3\Pi \rightarrow$ X $^3\Pi$, ground state.

λ	I	v′, v″	λ	I	v′, v″
4850·1	3	0, 1 R_1	4521·3	3	3, 2 R_1
4847·2	3	0, 1 R_2	4519·3	3	3, 2 R_2
4827·5	4	0, 1 R_3	4496·2	4	2, 1 R_1
4644·7	5	1, 1 R_3	4493·8	4	2, 1 R_2
4640·6	10	0, 0 R_1	4471·5	5	1, 0 R_1
4637·9	9	0, 0 R_2	4469·5	4	1, 0 R_2
4619·8	8	0, 0 R_3			

β System, Yellow

Transition. B $\rightarrow$ X $^3\Pi$, ground state.

λ	I	v′, v″	λ	I	v′, v″
6070·0	3	1, 2 R_3	5629·0	6	0, 0 R_2
5809·2	4	3, 3 R_3	5551·7	5	0, 0 R_1
5778·5	5	2, 2 R_3	5545·2	3	4, 3 R_3
5748·1	8	1, 1 R_3	5515·3	3	3, 2 R_3
5724·0	6	0, 0 Q_3	5491·7	3	5, 4 R_2
5718·1	10	0, 0 R_3	5485·7	3	2, 1 R_3
5658·1	5	1, 1 R_2	5456·5	4	1, 0 R_3

γ System, Red

Transition. A $^3\Sigma \rightarrow$ X $^3\Pi$, ground state.

λ	I	v′, v″	λ	I	v′, v″
6996·3	3	3, 4 R_3	6324·3	3	3, 3 R_1
6959·9	3	2, 3 R_3	6292·8	7	2, 2 R_1
6543·0	5	2, 2 R_3	6260·9	8	1, 1 R_1
6508·1	9	1, 1 R_3	6229·4	9	0, 0 R_1
6473·7	10	0, 0 R_3	6021·3	3	1, 0 R_2
6412·3	6	2, 2 R_2	5977·7	3	3, 2 R_1
6378·3	8	1, 1 R_2	5439·4	4	5, 2 R_1
6344·9	9	0, 0 R_2			

Ultra-violet Systems

References. G. H. Herbig, *Astrophys. J.*, **109**, 109. (1949)†.
M. Afaf, *Nature*, *Lond.*, **164**, 752. (1949).

Bands degraded to the red have been arranged into three systems by Afaf, whose measurements are given below. Many of these bands were also observed by Lowater, whose list, however, included some Zr lines.

3682 *A. System, probably* $^1\Sigma \rightarrow {}^1\Sigma$

λ	I	v′, v″	λ	I	v′, v″
3981·4	3	1, 3	3589·9	6	2, 1
3818·3	4	0, 1	3572·0	8	1, 0
3700·1	1	1, 1	3486·7	2	3, 1
3682·1	10	0, 0	3390·0	1	4, 1

ZrO (*contd.*)

3507–3472 A. *System, perhaps* $^3\Delta \rightarrow {}^3\Pi$ *ground state.*

λ	*I*	*v′, v″*	λ	*I*	*v′, v″*
3507·6	1	0, 0 Q_3	3491·8	3	0, 0 R_2
3506·3	3	0, 0 R_3	3473·6	1	0, 0 Q_1
3493·1	1	0, 0 Q_2	3472·4	3	0, 0 R_1

3060–2940 A. *System, perhaps* $^3\Pi \rightarrow {}^3\Pi$.

λ	*I*	*v′, v″*	λ	*I*	*v′, v″*
3052·4	1	0, 1 R_3	2967·8	2	0, 0 R_3
3033·5	1	0, 1 R_2	2950·0	2	0, 0 R_2
3023·8	1	0, 1 R_1	2940·9	2	0, 0 R_1

INFRA-RED BANDS

References. W. F. Meggers and C. C. Kiess, *Nat. Bur. Stand. J. Res.*, 9, 325. (1932).
M. Afaf, *Thesis*, *Ph.D.*, London. (1949)†.

Meggers and Kiess reported a complex group of weak bands, degraded to the red, in the region 9500–9200 A. Afaf found a similar group in the region 8950–8500 A. and suggested that the two groups form the (0, 0) and (1, 0) sequences of a system of bands with five heads.

Strongest heads from these authors :—

λ(*I*) ; 9370·7 (3), 9360·3 (3), 9356·1 (3), 9329·9 (5), 9315·9 (5), 9299·6 (5), 8744·1 (2), 8734·0 (2), 8721·3 (3), 8709·3 (3), 8695·2 (3).

Afaf also reported a strong band with a conspicuous, though somewhat weak head at λ8192 accompanied by a weaker band at λ8210 and a number of fairly strong bands without conspicuous heads in the region 7900–7600 A.

PRACTICAL HINTS

THE FOLLOWING SECTION contains a few brief notes on various minor points which arise in the identification of molecular spectra, and which have been found to trouble the inexperienced, but which are not usually dealt with in the general textbooks.

On the Identification of Bands. It should be borne in mind that the most satisfactory comparison of two spectra is made by bringing plates or prints together, side by side. It is preferable that the spectra should be taken with the same instrument in the same state of adjustment, but if this is not possible, enlargements from the plates may be made to the same scale by means of the iron arc comparison spectra. That such direct comparison is not always necessary is of course true ; in fact, the object of constructing these tables is largely to make this unnecessary ; nevertheless, there will remain cases where one must resort to this method. This is especially true in dealing with sources of very low intensity, such as phosphorescent glows, fluorescence, the night sky, comet tails, etc., where, in order to get a record in a reasonable time, instruments of small dispersion are used with wide slits. In such cases, while the wave-lengths recorded by the observer are not infrequently useless for identification, much may be done with his published photograph. Direct comparison is also useful in dealing with spectra which consist of small regions of continuum, headless bands or other structures lacking outstanding features capable of accurate measurement, and in dealing with spectra which contain several band systems superimposed. Small differences in complicated spectra, otherwise the same, and points of resemblance in spectra mainly different are certainly most readily detected by direct comparison.

Where the dispersion is sufficient to allow of reasonably accurate measurements on well-defined heads, identification by means of wave-lengths becomes practicable. In using these tables the following procedure is suggested as a guide :—

(1) Select two or three of the strongest bands of the spectrum to be identified and compare their wave-lengths with the list of persistent bands. If entries are found in close agreement with these wave-lengths, and if the bands are degraded in the appropriate direction, refer to the detailed list for the corresponding system.

(2) If all of the bands given in the detailed list are found to be present in the spectrum and the details of appearance and occurrence are applicable, the identity may be considered to be established. The approximate agreement of a few of the bands should not be accepted as identification unless the selection can be reasonably explained, *e.g.*, in absorption it may happen that only those bands with $v'' = 0$ are obtained or in fluorescence only those arising from certain values of v' ; a random selection should be rejected. If bands remain unaccounted for in the spectrum they may be an extension of the system, if they are the same type of band, or they may belong to another system of the same molecule. If bands are still outstanding after these possibilities have been examined, select the strongest of them and refer again to the list of persistent bands.

(3) Having identified as many systems as possible by this method, it is usually worth while to refer to the detailed lists for systems of other molecules which may be formed from the elements now known to be present. In this way weak bands which have escaped notice in a crowded spectrum are often detected and accounted for.

(4) Determine the origin of strong atomic lines if any are present. This may provide a clue to an identification, support one already made, or supply the clearest evidence of an unsuspected impurity.

(5) Consider whether the systems obtained are likely to occur in the given source. Such considerations often help to eliminate erroneous identifications due to chance coincidences.

Sources. It is desirable to have some acquaintance with the properties of various sources commonly employed for the production of spectra, both in regard to choosing a source suitable for the production of a given spectrum, and also in regard to assessing the probability of a suspected system appearing in the given source.

The evaluation of the absolute intensities of the band systems of a molecule in different sources requires a knowledge of such quantities as the concentrations of the various atoms and molecules present, the proportion of each in their possible states of excitation and ionisation, with their velocity distributions, as well as the concentration and velocity distribution of electrons, and, in addition, a knowledge of the collision processes which may occur. Such knowledge is not in general available, but fortunately it is possible to make a few generalisations of some value as a result of direct observation, without going into so much detail.

Flames. Many band systems are observed in flames; some by the direct combustion of inflammable substances; others by the introduction of additional substances into a flame already established. The general characteristic of the band systems obtained in this way is that they arise from transitions between a few of the lowest levels of the molecule concerned. The energy of the upper level involved rarely exceeds 5 e-volts, while the lower level is in most cases the ground state. Without exception, flame bands have been found to belong to molecules which are electrically neutral, but very frequently the molecules are not stable in the chemical sense, thus such combinations as CH, NH and OH are of very common occurrence. A few examples will serve to illustrate these points. The 4300 A. and 3900 A. bands of CH, the 3064 band of OH and the Swan bands of C_2 appear readily enough in the flames of hydrocarbons, but the Third Positive and the Angstrom bands of CO, which require more than 10 electron volts for their excitation, are absent. Different systems occur most strongly in different parts of the flame; the OH bands are spread through the blue outer cone of a Bunsen flame using coal-gas, but the Swan bands are restricted to the greenish inner cone of the roaring flame, which in fact owes its colour mainly to the presence of these bands. The 3360 A. band of NH, the 3064 A. band of OH and the red and violet systems of CN are given by a flame of moist cyanogen. The 3360 A. band of NH is also obtained strongly from the oxy-ammonia flame, but the systems arising from more excited levels, which are known from other sources, do not appear as well. This is also true of the cyanogen flame. To obtain other systems by the introduction of additional substances, it is necessary that these should be brought to the gaseous state within the flame. Gases and vapours may be mixed directly with the gas being burnt; volatile liquids may be sprayed into the flame and volatile solids introduced on suitable supports. The number of spectra which may be obtained in this way is thus restricted by the necessity of finding suitable volatile substances to add to the flame. This restriction is not so far reaching as it appears at first sight, since the substance whose spectrum is required does not have to be introduced directly, but may be formed as a result of chemical reaction within the flame. Thus in the example mentioned above, although carbon is among the least volatile of all substances, yet the bands of C_2 are readily observed during the combustion of hydrocarbons, even

being observed in a candle flame. Again, in cases where the metallic oxide is refractory, the spectrum of the oxide may be obtained by introducing the metal itself or, more generally, by introducing a volatile halide. Chemical action in the flame also allows the spectra of many metal hydrides to be obtained from flames in cases where the metal does not form a stable compound with hydrogen. Thus the spectra of MgH and CuH may be obtained by putting the finely divided metal into a hydrogen flame and that of NiH by allowing the vapour of nickel carbonyl to mix with the hydrogen. In the examples quoted so far the band systems obtained from flames are readily obtained in other ways, from the electric arc or the discharge tube for the most part, but there are a few systems known which appear readily in the flame yet are not obtained or are only obtained with difficulty in other sources. Such are the CO-flame bands, the ethylene-flame bands and the α-bands of ammonia. It is unlikely that such systems arise from highly excited states of the molecules concerned; it appears more probable that the equilibrium configurations for the excited states differ considerably from those for the normal state. According to the Franck-Condon theory excitation by the absorption of light or by electron impact takes place in such a way that the instantaneous kinetic energy and configuration of the nuclei are unchanged during the change of electronic state; therefore in absorption or in sources where excitation is mainly by electron impact, band systems arising from states in which the configuration of the nuclei differs markedly from that of the normal state may be expected to be weak. In the flame, where excitation occurs mainly as a result of collisions between atoms and molecules, these systems may be relatively strong.

The Arc. In general, arcs develop higher temperatures than flames and therefore are able to volatilise many substances which resist flames. The arc spectra of atoms contain many more lines than the flame spectra, for there is usually sufficient energy available in collision processes in the arc to excite all states up to ionisation, and, in the case of readily ionised elements like calcium, even to excite a few states of the ion. With molecules the behaviour is similar; in the arc spectrum more band systems appear than in the flame spectrum as higher levels are excited. The number of additional systems is not usually great, however, for just as in atomic series the number of lines distinguished is limited by the pressure, so other factors, including pressure, limit the number of band systems. The arc in air has been widely used for the production of the spectra of oxides and halides of the metals; in some cases, such as CuCl and TiO, the bands are more clearly shown in the flame of the arc than in the core. By enclosing the arc it may be run in various gases and at various pressures ranging from a few millimetres of Hg to several atmospheres. The spectra of many of the metallic hydrides have been obtained using arcs in hydrogen at a pressure of a few centimetres of mercury. Reduction of the pressure favours ionisation; thus the spectra of Mg^+ and MgH^+ can be obtained easily from an arc between poles of magnesium in an atmosphere of hydrogen by reducing the pressure to a few millimetres of Hg. Increase of pressure up to several atmospheres is sometimes successful in producing band systems not otherwise obtained, such as those of SnH and PbH. This occurs where states of the molecular are subject to predissociation. Band spectra emitted by arcs do not necessarily arise from molecules containing the material of the poles, sometimes only the atmosphere is involved; many arcs produce the OH bands if water vapour is present, and several, notably the Cu arc, produce the NO γ-bands in air. Under reduced pressure such bands as those of PN, NH 3360 A. and the Second Positive system of nitrogen are produced when the appropriate elements are present in the atmosphere. (For high-tension arc see "The Spark.")

Discharge Tubes. Although, as sources of illumination, flames and open arcs have the advantage of simplicity, discharge tubes offer greater scope for the variation of conditions. The discharge tubes formerly used were of low intensity but many of the types now in use compare favourably with the arc in this respect. Moreover, discharge tubes have the additional advantage of steadiness, so that continual readjustment of the image of the source on to the slit is avoided. In what is called the normal discharge seven different regions have been distinguished, viz.: (1) the anode glow, (2) the positive column, (3) the Faraday dark space, (4) the negative glow, (5) the cathode dark space, (6) the cathode glow and (7) the primary dark space. The most luminous parts and therefore those most used in spectroscopy are the positive column and the negative glow.

The Positive Column. With an uncondensed discharge the positive column presents a source which resembles the arc in many ways. The spectra obtained from it are usually those of uncharged atoms and molecules but the number of excited states reached is greater than in the flame or the arc in air. Thus with CO or CO_2 present the Fourth Positive and Angstrom bands of CO appear readily in the positive column although they are not observed in the CO flame and only with difficulty in the arc. Excitation appears to be due mainly to electron impacts, the electrons having a velocity distribution of the Maxwell-Boltzmann type but for a temperature much higher than that of the gas molecules in the tube. The actual distribution depends very much on the nature and pressure of the gas in the tube and on the intensity of the electric field along the column. Both lowering the pressure and increasing the intensity of the field tend to favour higher stages of excitation; the variation takes place in such a way that the state of excitation appears to depend mainly on the ratio of the field to the pressure, X/p, or perhaps rather more accurately on $X.\lambda$, the product of the field and the mean free path of the electron.

The Negative Glow. In the region of the negative glow there accumulates a considerable positive space-charge. The ions are excited to emission by electrons from the direction of the cathode and as a result the negative glow gives largely the spectra of positively charged ions. A modification of the form of the cathode, known as the hollow cathode, allows fuller advantage to be taken of this peculiarity of the negative glow. The cathode takes the form of a hollow cylinder or a massive block through which a slot has been cut. For a certain range of pressure the negative glow passes into the recess, becoming at the same time more brilliant. For the production of molecular spectra the linear dimensions of the recess are usually greater than for the types of hollow cathode used for the production of fine lines for the study of hyperfine structure.

The Addition of Other Gases. Several molecules are known to emit somewhat different spectra in the presence of different gases. Thus, in the presence of excess of one of the rare gases, CO is found to give the Cameron bands and the Triplet bands. Again, whereas the positive column in pure nitrogen appears of an orange colour, the addition of oxygen causes the colour to change to pink, due to a weakening of the red and yellow bands of the First Positive system of N_2 relative to the blue and violet bands of the Second Positive system. The mechanism in most cases is still somewhat obscure. The following, however, are processes which may be expected to occur. If the excess is an inactive gas, such as one of the rare gases, then excited molecules which ordinarily lose their energy in a collision with their fellows may collide with rare gas molecules without loss of energy. There is then greater probability of the molecule radiating band systems arising from these particular excited states. This is especially

likely to be true for metastable states of the molecule. On the other hand, if there are metastable states of the molecules of the added gas which are excited, these may in a collision hand over their energy to the other molecules, thereby exciting states of these molecules which are not readily excited by electron impact. Also, there is the possibility that the excess of other gas may so modify the velocity distribution of the electrons as to cause a marked change in the relative numbers of molecules excited to different levels.

Controlled Electron Sources. The variation of intensity of the various band systems of a molecule with the velocity of impacting electrons can be studied more accurately in discharge tubes where the velocity can be adjusted as desired. Such tubes usually consist of a heated wire as a source of thermionic electrons, and a grid separated from it by a distance less than the mean free path of an electron at the pressure at which the tube is to be used. By varying the voltage across the grid and filament, the velocity of the electrons can be gradually increased until light is emitted from the gas in the tube. This indicates that molecules of the gas are being raised to an excited state; as the voltage is still further increased, other excited states are reached with the consequent emission of other band systems.

High Frequency Discharges. Two kinds of high-frequency discharge are used fairly extensively in spectroscopic work. They are often spoken of as the ring discharge and the valve oscillator discharge respectively. In the ring discharge a condensed spark is used to set up damped oscillations in a circuit containing suitable inductance and capacity. The inductance consists of a coil of a few turns wound around a spherical or cylindrical vessel containing gas or vapour at low pressure. Under these conditions the gas or vapour may be made to glow brilliantly, the spectra emitted depending on the violence of the discharge, which may be controlled by varying the length of the spark gap. As the violence is increased, the spectrum may be made to change from bands due to molecules to lines due to atoms which have lost several electrons. Decrease of pressure favours greater excitation as with other forms of discharge. In the valve oscillator discharge, a thermionic valve is used to maintain continuous high frequency oscillations in a tuned circuit. A tube containing gas at low pressure may be made to emit radiation by connecting the oscillating circuit to electrodes of the usual type, to external electrodes consisting of foil wrapped around the outside of the tube or to a wire coiled about the tube in the form of an inductance as with the ring discharge. The valve oscillator as generally used with a plate voltage of 1,000–2,000 volts gives spectra which resemble those of the positive column at higher pressures but tend to change to those of the negative glow as the pressure is reduced. High frequency discharges provide a useful means of exciting afterglows and have the advantage that contamination with material from electrodes can be avoided.

Tesla Discharge. The electrodeless discharge from a Tesla coil or " leak tester " generally gives a rather similar spectrum to that of the positive column from a discharge from an induction coil, but it seems to produce less chemical dissociation. It is thus particularly suitable for exciting the electronic spectra of polyatomic molecules such as benzene, glyoxal and formaldehyde ; for this purpose a continuous flow of gas through the discharge tube should be maintained.

Active Nitrogen. The ring discharge or condensed discharge through carefully purified nitrogen are both capable of giving rise to a strong orange-coloured afterglow. The spectrum of this afterglow consists of some of the bands of the First Positive system of N_2. If a small amount of oxygen is mixed with the nitrogen some of the bands of the β-system of NO also appear ; in fact, this system is best obtained in this way.

In the positive column of a discharge tube the γ-system is much stronger than the β-system, whereas in the afterglow the reverse is the case. The equilibrium constants for the upper state of the γ-system are much closer to those of the normal state than are those for the upper state of the β-system. Many other band systems can be excited by introducing appropriate gases or vapours into nitrogen thus activated, the excitation often being accompanied by chemical reaction. Thus organic compounds such as CCl_4 and C_2H_2 yield systems of CN, CH, C_2, and sometimes NH; $SiCl_4$ yields SiN systems; and, with a trace of oxygen, BCl_3 yields systems of BO. It is usually difficult to remove all trace of oxygen, so that band systems of the oxides often occur quite strongly when other compounds, such as the halides of metals, are added to active nitrogen. A band system produced in active nitrogen often differs considerably in appearance from the same system as observed in the arc or discharge tube; the violet CN bands form a good example. The bands produced in active nitrogen have much shorter branches than in the arc but many more bands of the system are observed; fewer states of rotation are excited, but more of vibration. The energy available for excitation is about 9½ electron volts.

The Spark. The condensed spark discharge is not much used for the production of molecular spectra, since the violence of the discharge is such that many lines of atoms in various stages of ionisation are produced, but few band systems. Sometimes, however, band systems are emitted in an afterglow following the passage of the spark and may be photographed if a synchronised shutter is adjusted to cut off the light of the spark itself from the spectrograph while exposing it to the afterglow. The uncondensed discharge is used in a variety of ways. The discharge from a high tension transformer between metal rods in air is useful for the production of the spectra of some metallic oxides, the bands being obtained with fewer atomic lines and with shorter branches than in the arc; this facilitates vibrational analysis. By enclosing the discharge it may be used to excite the spectra of various gases and vapours, *e.g.*, the Schumann-Runge bands in O_2. The uncondensed discharge has also been used in conjunction with flames, in some cases to increase the intensity of bands emitted by the flame itself, and in other cases to introduce the vapour of metals of high melting point into the flame for the production of the spectra of their oxides or hydrides. The spectra of the hydrides of nickel, manganese and chromium have been produced in this way by passing the discharge between poles of the appropriate metal in a flame of hydrogen.

Absorption. It is frequently convenient to observe band systems in absorption and this is particularly true where polyatomic molecules are concerned, for these are usually decomposed in emission sources. Observed in absorption a molecular spectrum differs in some respects from one taken in emission. Unless the temperature is unusually high, absorption only occurs for those systems which have the normal state of the molecule as lower level, and only for those bands of these systems which start from the first two or three vibrational levels of the normal state. Thus the absorption spectrum is in general much more simple than the corresponding emission spectrum. If the nuclear configuration for the equilibrium position of the upper state of a system is very different from that for the lower state it may happen that the absorption spectrum shows few if any bands in common with the emission spectrum. In absorption, transitions take place from a few of the lowest vibrational levels of the lower electronic state to high vibrational levels of the upper electronic state, while in emission, transitions take place from a few of the lowest vibrational levels of the upper state to high vibrational levels of the lower state. Since the spacing of the vibrational levels

is different for the two electronic states, it is sometimes difficult to recognise that the bands belong to the same system. This applies particularly to polyatomic molecules.

It is sometimes desired to establish proof of the presence of a molecule, especially if this is a radical not stable chemically, by attempting to observe its spectrum in absorption. Sufficient consideration is not, however, always given to the conditions which must be fulfilled for this observation to be possible. The individual lines of band structure are usually very sharp and will only be observed in absorption if the power of resolution of the spectrograph is comparable with the width of the lines themselves. This usually means that an instrument of high dispersion must be used and the slit kept as narrow as possible. This point is well illustrated by observing how the number of Fraunhofer lines which can be distinguished in the solar spectrum depends on the resolving power of the spectrograph used and on the width of the slit. Since the width of an absorption line depends on the number of absorbing molecules in the line of sight, an increase of the length of absorbing column improves the chance of observing the line, but often, as in dealing with flames and explosions, such increase is limited. Lines crowded together to form heads resemble wide lines and as such may be observed with smaller resolution than is necessary to show the individual lines. It often happens therefore that the head of a band may be observed in absorption but not the open branches which accompany it when it is observed in emission with the same spectrograph.

Collimation. Beginners are sometimes troubled by unduly long exposures, lack of definition, doubling and shading of the lines, these defects arising from poor collimation. Whenever a spectrograph is used, care should be taken to see that it is collimated so that it is used to the best advantage ; and this includes the giving of due consideration to the selection and adjustment of optical parts, such as condensing lenses, placed between the source and the slit. Assuming that the optical parts of the spectrograph are without fault, it is essential, to obtain speed and good definition, that the dispersing system, prism or grating, should be uniformly filled with light. At the same time, it is undesirable that additional light should be admitted to the spectrograph through the slit as this extra light, which does not pass through the optical system, is merely scattered within the instrument causing a background of fog on the plate. The ideal is therefore that the light entering the slit should diverge from it in the form of a cone with its axis along the optical axis of the collimator and its base just filling the optical system. If the source is sufficiently extended, it may be brought near enough to the slit for this condition to be fulfilled ; if it is not, a condensing lens must be used. In either case, the first adjustment is to arrange the source so that it is on the axis of the collimator. A simple procedure for making this adjustment is as follows : The slit of the spectrograph is opened to about 1 mm. and the source moved (the standard iron arc is convenient for this purpose) both laterally and vertically until the narrow pencil of light entering the slit falls on the centre of the prism or grating of the spectrograph. If a condensing lens is to be used it is next put in place so as to focus an image of the source on the slit. It is an advantage to use the enlarged rather than the diminished image on the slit, provided care is taken to ensure that the full aperture of the spectrograph is used. Use of the diminished image does not give an increase of speed proportional to the brightness of the image, since the light is spread over a cone of larger solid angle, thus more than filling the optical system and flooding the spectrograph with light. The diminished image also has the additional disadvantage of giving a very narrow and uneven spectrum. When the source and lens have been set in position the adjustment should be checked by placing the eye in the plane of the

spectrum and observing whether the optical system is completely and uniformly filled with light. When collimating it is often useful to remember that light travelling in the opposite direction takes the same path through an optical system. Thus with large concave gratings, where the grating and source rooms are separate, it is convenient to place a small strip of white paper in front of the grating, illuminate it so that it may be seen through the slit from the source room, and then to place the arc (with current off) in line with the paper and the slit. The lens may then be arranged to focus the image of the arc on the slit. Again, if a source is difficult to move when running it may be set in position, once the lens has been fixed, by illuminating the slit, finding the real image of the slit, and then adjusting the source to coincide with this image. In the majority of experiments a condensing lens is used. Once the lens has been adjusted to be on the axis of the instrument it may be kept there and the source changed as required, the source automatically coming on to the axis when its image is focused on the slit. If the work is sufficiently routine, it may be worth while to arrange an optical bench in conjunction with the spectrograph. Concave mirrors may also be used to focus the source on to the slit and have the advantage that the image is achromatic. Mirrors, however, are otherwise inconvenient and lenses are generally preferred. It must be remembered, when using a lens, that the different wave-lengths come to a focus at different distances from the lens. With large instruments, when only a small region of the spectrum is being photographed at a time, this is not serious if care is taken to focus for the wave-length region required, but with small instruments covering a large range, such as the usual quartz spectrographs, it may lead to great variations of intensity. If a particular region is required the lens may be adjusted to bring this to a focus, but if the whole range is required, as in exploratory work, it is usually of advantage to focus the farthest ultra-violet image on the slit. This may be done by using a fluorescent screen in front of the slit and a source, such as the copper arc, which is rich in lines about 2100 A. to adjust the lens. In this way a very uniform intensity may be obtained from the visible to the far ultra-violet.

Comparison Spectra. To obtain the wave-lengths of features of a spectrum, a comparison spectrum is photographed alongside. The comparison most generally used is the iron arc. The spectrum of the iron arc contains a very large number of sharp strong lines distributed fairly evenly from about 2330 A. to the infra-red region ; there are one or two gaps and the orange region is somewhat confused by bands of FeO, but on the whole it is good throughout the visible and near ultra-violet regions. The lines have been investigated by the International Astronomical Union and accurate standard values of their wave-lengths set up. To obtain the highest accuracy the form of arc lamp used to produce the spectrum has been standardised following the recommendations of Pfund. The electrodes are vertical ; the anode below, consisting of a bead of iron oxide supported on a massive rod of iron, and the cathode above, consisting of a rod of iron 6–7 mm. in diameter, having a massive cooling cylinder of copper or iron close to the end of the rod. The arc is operated on a 110–250 volts supply with a current of 5 amperes or less. For accurate measurements the arc should be 12–15 mm. long and light should be taken only from the central zone at right angles to the axis of the arc not exceeding 1·5 mm. in width.

For the region 2000–2300 A. the copper arc is employed. Since the spectrum of the copper arc is relatively simple it is sometimes used as a general comparison spectrum for work with small dispersion. The practice is not, however, much to be recommended as the appearance of the spectrum is rather variable, there are few lines at the red end of the spectrum, and bands of NO often confuse the ultra-violet region.

Mercury shows far too few lines to be of much use as a comparison spectrum, but the frequent employment of the mercury arc as a source for fluorescence and photochemistry has led to its adoption for this purpose. The principal features of the spectrum are of course very easily recognised.

For the yellow and red regions a neon spectrum has been recommended. A neon discharge tube is a very convenient source but unfortunately the lines are rather far apart for use with high dispersion and the useful range is very limited. For the photographic infra-red, a barium arc (Ba salt on carbon poles) is a useful wave-length guide for work with small dispersion.

Reproductions of the spectra of iron, copper, mercury and neon are shown in Plates 11 and 12.

Measurement. If a spectrum is to be measured the comparison spectrum should be photographed alongside, so that there is a slight overlap. In doing this the adjustments of the spectrograph, the plate holder and the dark slide should not be disturbed between the two exposures ; the spectra are brought into the desired positions by use of a Hartmann diaphragm in front of the slit for a prism instrument, and by use of a Rowland shutter in front of the plate for a grating instrument.

To obtain the wave-lengths, a travelling microscope with a screw accurate to 0·001 mm. is used to measure the positions of the bands or lines under investigation and a sufficient number of lines of the comparison spectrum. Care should be taken always to approach the line or band from the same direction, and after completing the measurements in one range the plate should be reversed, end to end, and a second run made. Reversal of the plate is very important when the lines measured differ much in definition or intensity, as individual observers show, as a rule, a tendency to set regularly off centre by an amount depending on the character of the line. Reduction to the mean setting is greatly facilitated if the scales of the microscope are graduated in both directions, as subtraction is thereby eliminated and there is no difficulty in identifying corresponding readings.

The microscope scale readings are converted to wave-lengths by use of a suitable interpolation formula. In the measurement of grating plates a linear formula,

$$\lambda = \lambda_0 + S.D$$

is used, where λ_0 is a constant depending on the zero of the scale, S is the scale reading and D is the dispersion of the spectrograph. Two carefully chosen lines of the comparison spectrum, one at either end of the range, are used to determine the constants of the formula ; the remaining comparison lines are used to construct a correction curve for deviations from this approximate formula. For prism spectrograms a three-constant formula,

$$\lambda = \lambda_0 + C/(S + S_0)$$

is generally used, where λ_0 is a constant depending on the material of the prism, C is a constant depending on the dimensions of the instrument, S is the scale reading and S_0 is a constant depending on the position of the scale zero. As before, the constants of the formula are obtained from carefully chosen standard lines, this time using one in the middle of the range as well as one at either end, and a correction curve is constructed from the remainder. In the measurement of short ranges the calculation is simplified by assuming an approximate round number for λ_0 and using two standard lines to give the other constants. With this procedure a correction curve is essential, and the corrections are larger than would be the case with the three constant formula,

but there is the advantage that the curve does not contain a point of inflection. If the standard lines are converted to wave-numbers a linear formula,

$$\nu = \nu_0 + S.K$$

for wave-numbers may be used. This is much easier for use with a calculating machine, but the formula is still less accurate than the last and places a correspondingly greater burden on the correction curve.

In measuring band heads the crosswires of the microscope should not be set on the extreme edge of the band, but an attempt should be made to allow for the finite width of a line by setting half a line width within the head. Unless this is done the value obtained for the wave-length of the head may vary considerably from spectrograph to spectrograph, and if a wide slit is used may lead to discrepancies of several angstroms.

In measuring very faint lines it is generally found to be of some slight advantage to use blue light to illuminate the plate; faint lines appear a little more distinctly with the shorter wave-length illumination, possibly on account of greater scattering by the grains of the plate.

Spurious Bands. When using a quartz spectrograph care should be taken to avoid the light from the source becoming polarised before reaching the spectrograph. With polarised light, interference between the ordinary and extraordinary rays may introduce into a continuum a banded structure not unlike a diffuse band spectrum. The bands are usually too regular to be mistaken for a real molecular spectrum when strong and isolated, but if superimposed on a band system may cause errors in measurements of wave-length and intensity. The light may be polarised if reflectors are used to bring the image on the slit. Light from a discharge tube is often slightly polarised, probably by reflections within the tube.

If plates are not rocked or brushed during development broad lines or bands may become more strongly developed at the edges than in the centre, giving a spurious resolution into two.

With long exposures in a well-lit room it is possible for sufficient diffuse daylight to enter the slit to record the solar spectrum with the stronger Fraunhofer lines, particularly the H and K lines of Ca^+. If their origin is not recognised, these may be attributed to absorption bands from the source in use.

DESCRIPTION OF PLATES

Below are given brief indications of the source used and of the type of spectrograph employed, viz., concave *grating*, *glass* prismatic instrument, or *E. 1* (large Littrow type) *E. 2* (medium) or *E. 3* (small) quartz spectrograph. Where the plate has been taken by other than one of the present authors this is indicated by the name in brackets.

Plates 1 to 10 all show positive enlargements, while the comparison spectra shown in Plates 11 and 12 are reproductions of negatives.

Plate 1. CaF. Calcium fluoride in carbon arc ; glass.
CaO. Calcium carbonate in carbon arc ; glass.
AlO. High tension arc between Al electrodes ; grating. (W. Jevons.)
AlCl. Discharge tube ; E. 1. (B. N. Bhaduri.)
SiO. Heated silica discharge tube ; grating. (R. F. Barrow.)

Plate 2. Angstrom, Herzberg and Triplet Systems of CO. Positive column of discharge through CO_2; glass. (A. Fowler.)
Third positive and 5B bands of CO. Positive column of discharge through CO_2 ; E. 2. (A. Fowler.)
Fourth positive bands of CO. Positive column of discharge through CO_2 ; E. 2. (A. Fowler.)
CO^+, first negative. Negative glow of discharge through CO_2 ; E. 2. (A. Fowler.)
CO_2 (or CO_2^+). Negative glow of discharge through flowing CO_2 ; E. 2. (A. Fowler).

Plate 3. N_2, first positive. Positive column of discharge through N_2 ; glass.
N_2, second positive. Positive column of discharge through N_2 ; E. 1. (R. C. Pankhurst.)
N_2^+. Negative glow of discharge through N_2 ; E. 2.
NO β. Active nitrogen ; E. 2. (A. Fowler.)
NO γ. Positive column of discharge through air ; E. 2.

Plate 4. H_2, blue region. Discharge through H_2 ; glass.
H_2, red region. Discharge through H_2 ; glass.
OH. Bunsen flame ; E. 2.
CH. Discharge (? acetylene) (?).
NH. Discharge through flowing NH_3 ; E. 2. (R. W. Lunt.)
CuH. High-tension arc in hydrogen flame ; E. 2.
ZnH. Zn in discharge through H_2 ; E. 2.
CdH. Hollow cathode ; E. 2. (E. W. Foster and A. G. G.)

Plate 5. NaH. Discharge through H_2 and Na vapour ; E. 2. (R. C. Pankhurst.)
MgH. Arc with Mg electrodes in H_2 ; glass. (A. Fowler.)
MgH^+. Arc with Mg electrodes in H_2 ; E. 1.
ZnH^+. Arc with Zn electrodes in H_2 ; E. 1.
PH. Discharge through H_2 and P_2 vapour ; E. 1.
MnH violet and blue systems. High tension arc between Mn electrodes in H_2 flame ; glass.
MnH green system. As above.
NiH. High-tension arc between Ni electrodes in H_2 flame ; glass.

Plate 6. Condensed discharge through N_2 ; E. 2.
NS. Uncondensed discharge through N_2 and sulphur vapour ; E. 1. (C. J. Bakker.)
NS. As above continued.
PO. P_2O_5 in arc in air between Cu poles ; E. 1.
P_2. Uncondensed discharge through $P_2 + H_2$; E. 2.

Plate 7. O_2. Schumann-Runge. High-tension arc in O_2 at atmospheric pressure ; E. 1. (M. W. Feast.)
O_2. Schumann-Runge continued.
O_2^+. Second negative. High-frequency discharge through O_2 ; E. 1. (M. W. Feast.)
O_2^+. Second negative continued.
O_2^+. Second negative continued, and first negative.

DESCRIPTION OF PLATES (*continued*)

Plate 8. O_2 Schumann-Runge absorption. 3 m. vacuum grating. (H. P. Knauss and S. S. Ballard, *Phys. Rev.*, **48**, 796 (1935).)
O_2 Schumann-Runge. Atmospheric absorption ; E. 3.
O_4. Absorption by oxygen at 50 atm. pressure ; E. 2. (Enlarged from a print kindly supplied by K. Wieland.)
NO_2. Absorption by heated NO_2 ; glass. (L. Harris and R. W. B. Pearse.)
SiF. Discharge through SiF_4 ; glass.
TiO. TiO_2 in arc with Fe electrodes ; glass. (A. Fowler.)
CO^+. Discharge at very low pressure ; glass. (A. Fowler.)
CH_2O. Tesla discharge through flowing formaldehyde vapour ; E. 2. (J. C. D. Brand.)

Plate 9. Bunsen flame. Inner cone ; E. 2.
Ethylene flame. Inner cone ; E. 2.
CO flame. E. 2 ; on process plate.
C_2, Swan. Discharge (? acetylene) ; glass (?).
CN, violet system ; glass.
CN, red system. CCl_4 in active nitrogen ; glass. (A. Fowler.)
CS and S_2. Sulphur in carbon arc ; E. 3. (L. C. Martin.)
FeO. Iron carbonyl in flame ; glass.

Plate 10. CuCl. Cuprous chloride in carbon arc ; glass.
CuO. Arc in air between Cu electrodes ; grating.
BO. Boric acid in carbon arc ; glass.
SO and SO_2. Discharge through flowing SO_2 ; E. 3. (B. N. Bhaduri.)
SO_2 absorption. Hydrogen continuum ; E. 2.
C_6H_6. Absorption by vapour ; hydrogen continuum ; E. 2.
CH_2O. Absorption by formaldehyde vapour ; hydrogen continuum ; E. 2. (G. H. Young.)
I_2. Absorption by iodine vapour ; incandescent filament ; glass.

Plate 11. Comparison spectra. Iron, copper and quartz mercury arcs, and neon discharge tube.

Plate 12. Comparison spectra. Iron arc.

PLATE I

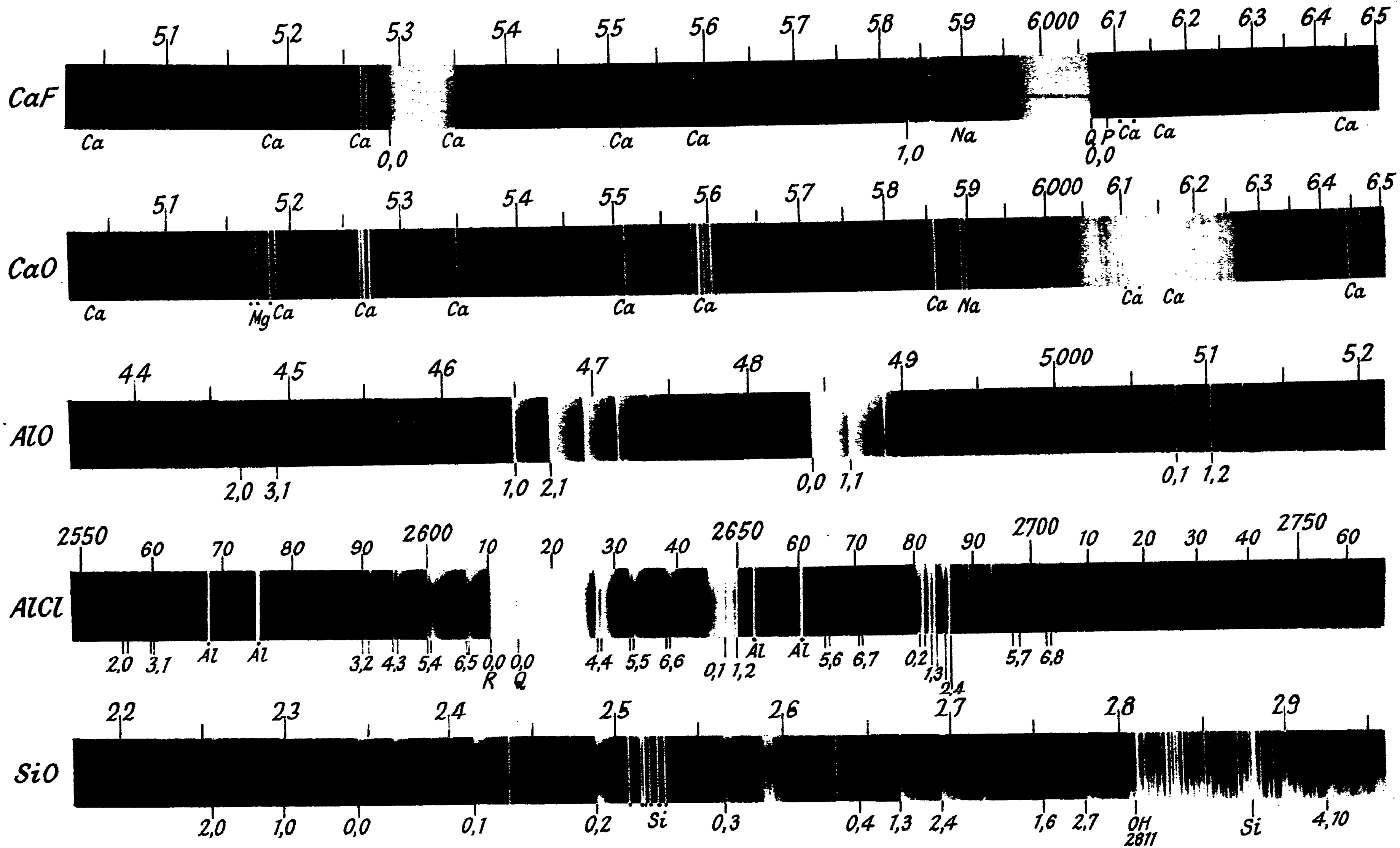


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PLATE 2

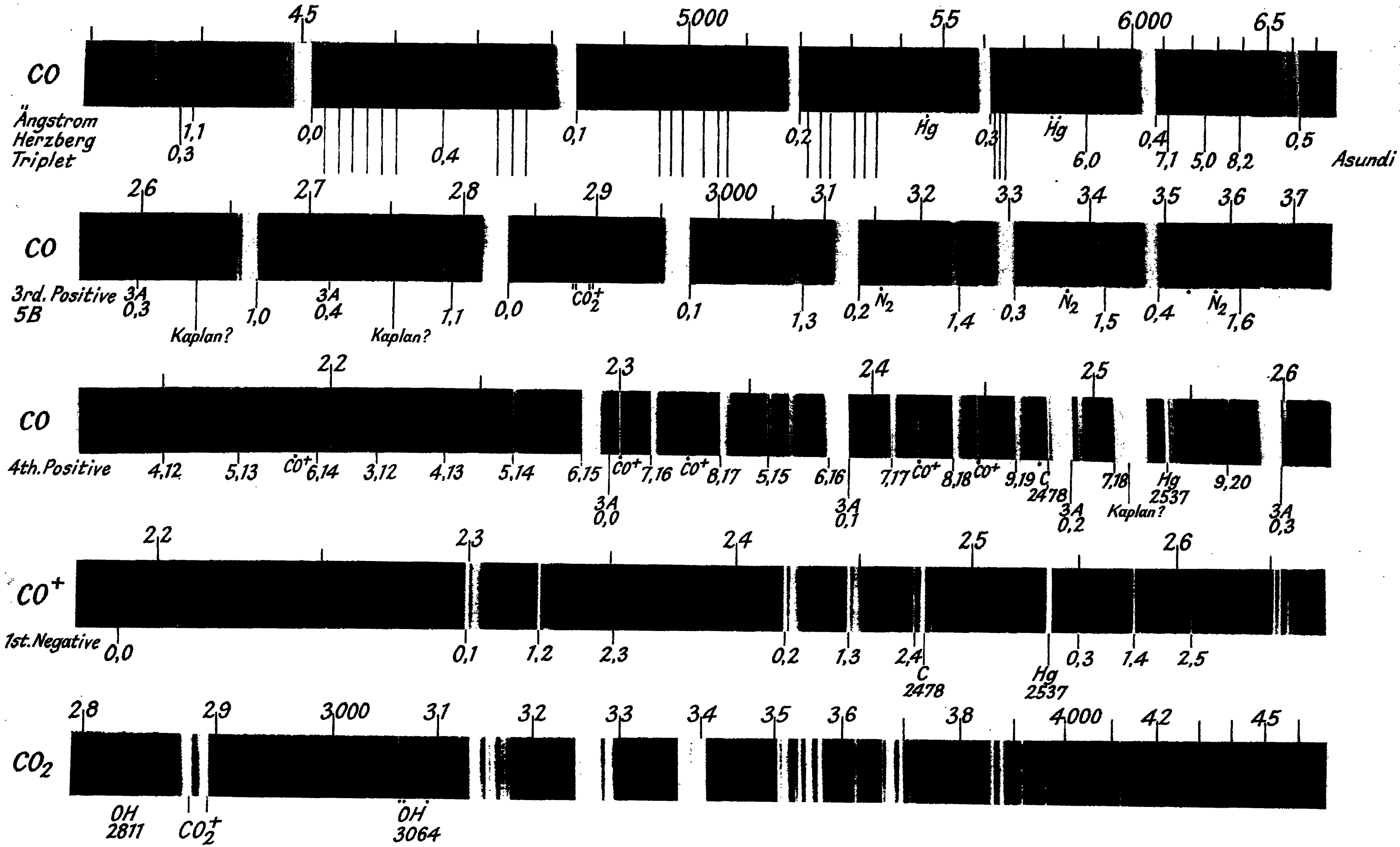
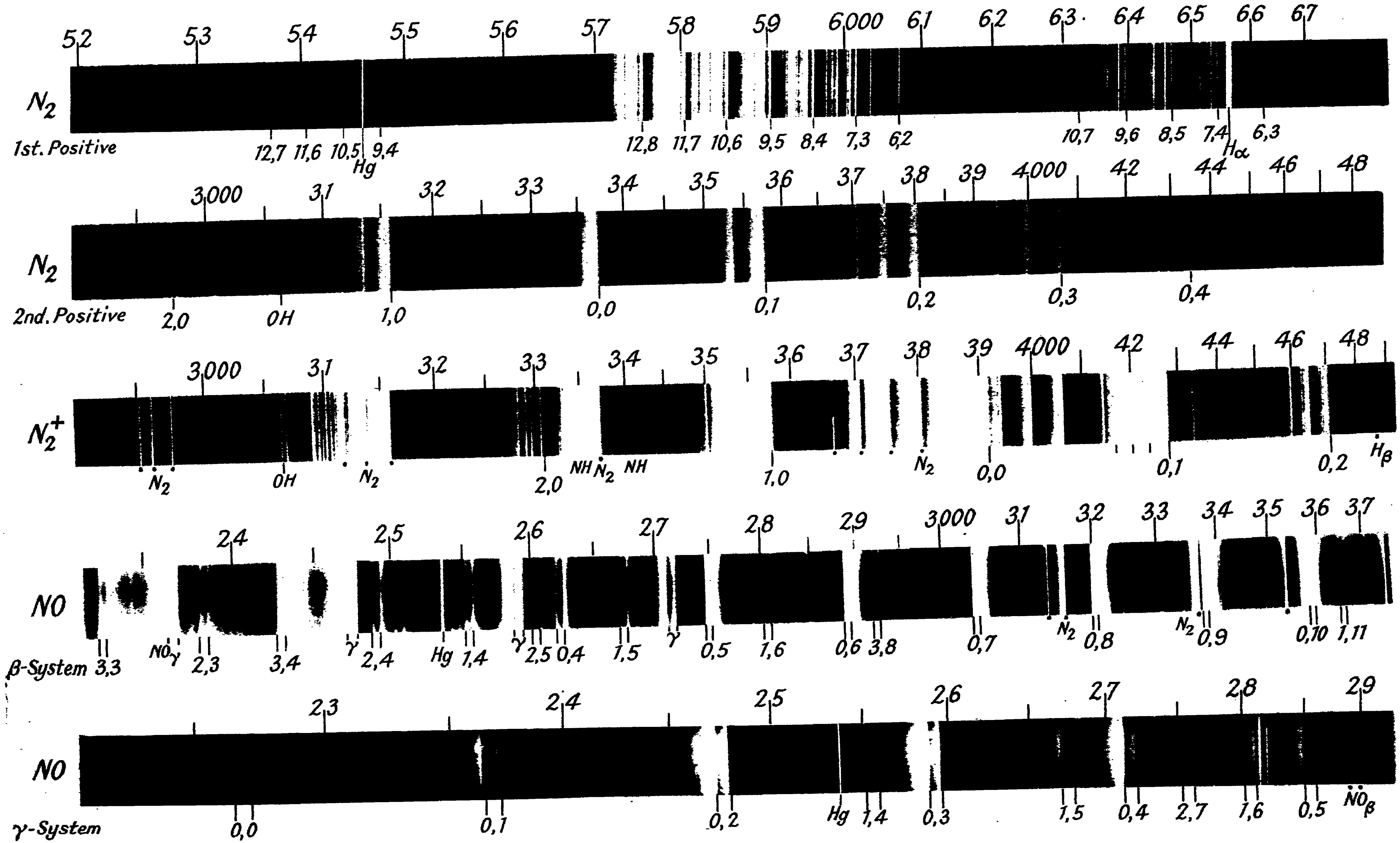
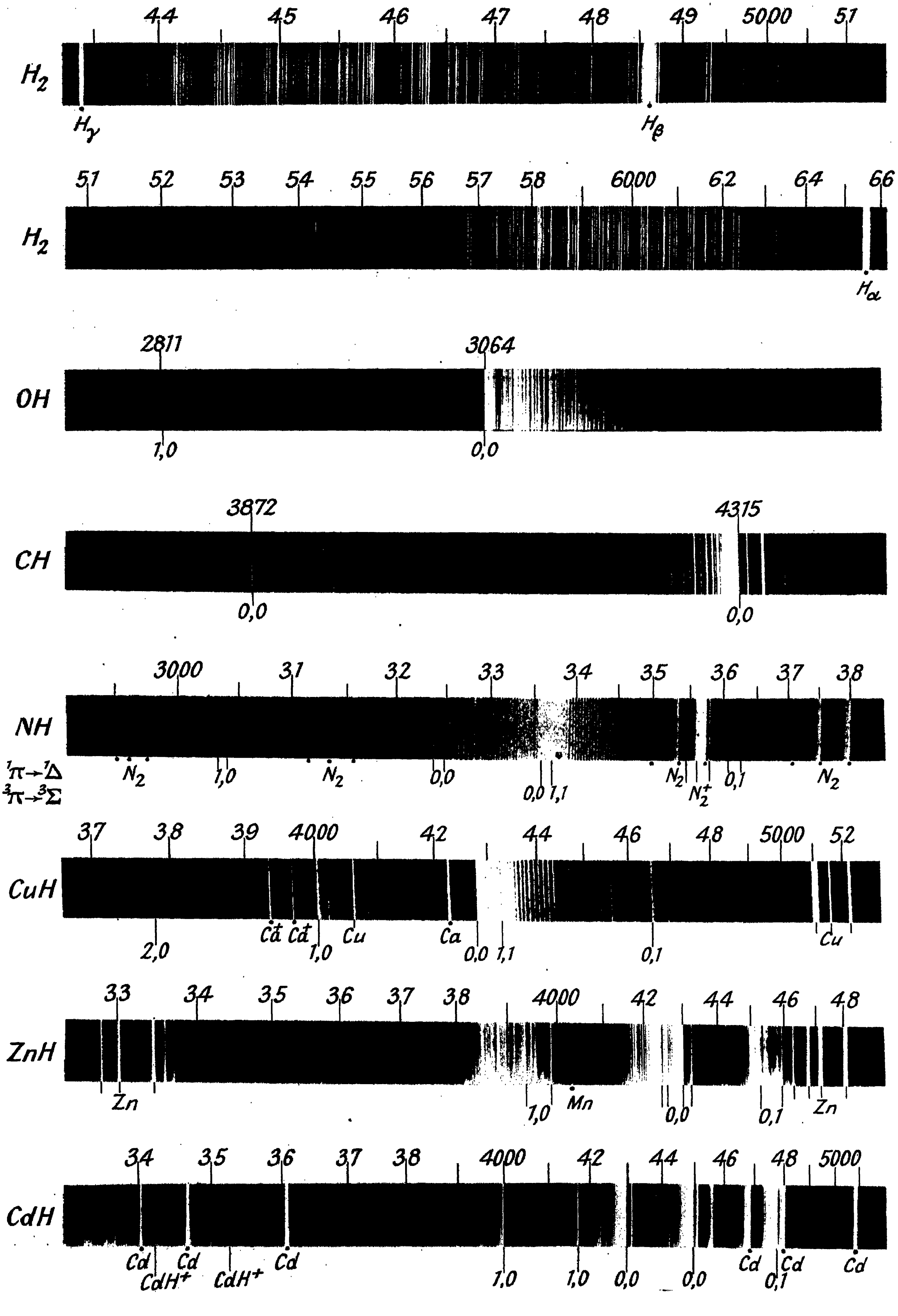

CO
Ängstrom
Herzberg
Triplet
Asundi
CO
3rd. Positive
5B
Kaplan?
CO
4th. Positive
Kaplan?
CO+
1st. Negative
Hg 2537
C 2478
CO2
OH 2811
CO_2^+
OH 3064

PLATE 3



N2
1st. Positive
5,2 5,3 5,4 5,5 5,6 5,7 5,8 5,9 6,000 6,1 6,2 6,3 6,4 6,5 6,6 6,7
12,7 11,6 10,5 9,4 Hg 12,8 11,7 10,6 9,5 8,4 7,3 6,2 10,7 9,6 8,5 7,4 Hα 6,3
N2
2nd. Positive
3,000 3,1 3,2 3,3 3,4 3,5 3,6 3,7 3,8 3,9 4,000 4,2 4,4 4,6 4,8
2,0 OH 1,0 0,0 0,1 0,2 0,3 0,4
N2+
3,000 3,1 3,2 3,3 3,4 3,5 3,6 3,7 3,8 3,9 4,000 4,2 4,4 4,6 4,8
N2 OH N2 2,0 NH N2 NH 1,0 N2 0,0 0,1 0,2 Hβ
NO
β-System
2,4 2,5 2,6 2,7 2,8 2,9 3,000 3,1 3,2 3,3 3,4 3,5 3,6 3,7
3,3 NOγ 2,3 3,4 γ 2,4 Hg 1,4 γ 2,5 0,4 1,5 γ 0,5 1,6 0,6 3,8 0,7 N2 0,8 N2 0,9 0,10 1,11
NO
γ-System
2,3 2,4 2,5 2,6 2,7 2,8 2,9
0,0 0,1 0,2 Hg 1,4 0,3 1,5 0,4 2,7 1,6 0,5 NOβ

PLATE 4



H2
44 45 46 47 48 49 5000 51
Hγ Hβ
H2
51 52 53 54 55 56 57 58 6000 62 64 66
Hα
OH
2811 3064
1,0 0,0
CH
3872 4315
0,0 0,0
NH
3000 31 32 33 34 35 36 37 38
1π→1Δ
3π→3Σ
N2 1,0 N2 0,0 0,0 1,1 N2 N2+ 0,1 N2
CuH
37 38 39 4000 42 44 46 48 5000 52
2,0 Cd+ Cd+ 1,0 Cu Ca 0,0 1,1 0,1 Cu
ZnH
33 34 35 36 37 38 4000 42 44 46 48
Zn 1,0 Mn 0,0 0,1 Zn
CdH
34 35 36 37 38 4000 42 44 46 48 5000
Cd CdH+ Cd CdH+ Cd 1,0 1,0 0,0 0,0 Cd 0,1 Cd Cd

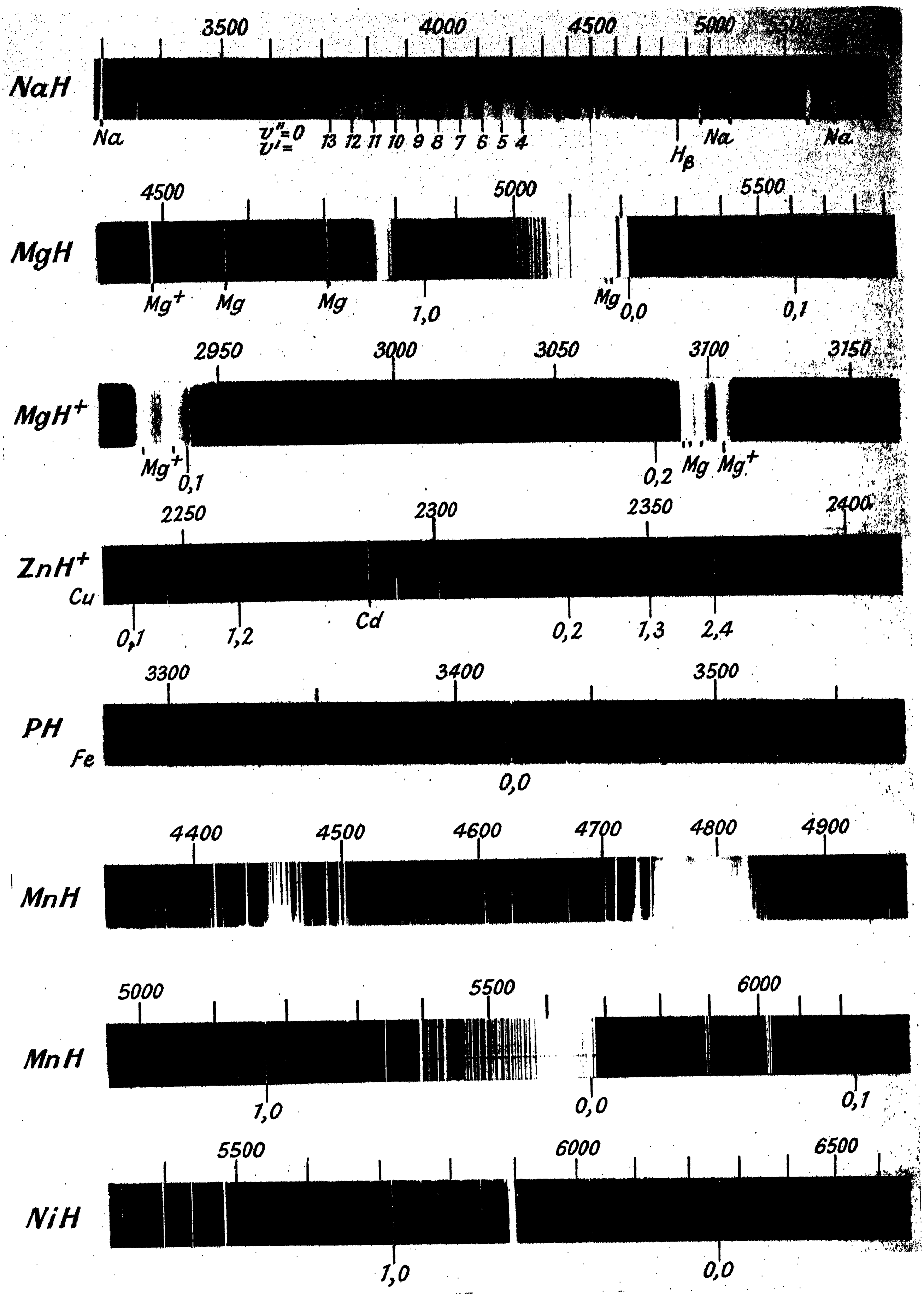

NaH
3500
4000
4500
5000
5500
Na
v''=0
v'=
13 12 11 10 9 8 7 6 5 4
H_β
Na
Na
MgH
4500
5000
5500
Mg^+
Mg
Mg
1,0
Mg
0,0
0,1
MgH^+
2950
3000
3050
3100
3150
Mg^+
0,1
0,2
Mg
Mg^+
ZnH^+
Cu
2250
2300
2350
2400
0,1
1,2
Cd
0,2
1,3
2,4
PH
Fe
3300
3400
3500
0,0
MnH
4400
4500
4600
4700
4800
4900
MnH
5000
5500
6000
1,0
0,0
0,1
NiH
5500
6000
6500
1,0
0,0

PLATE 6

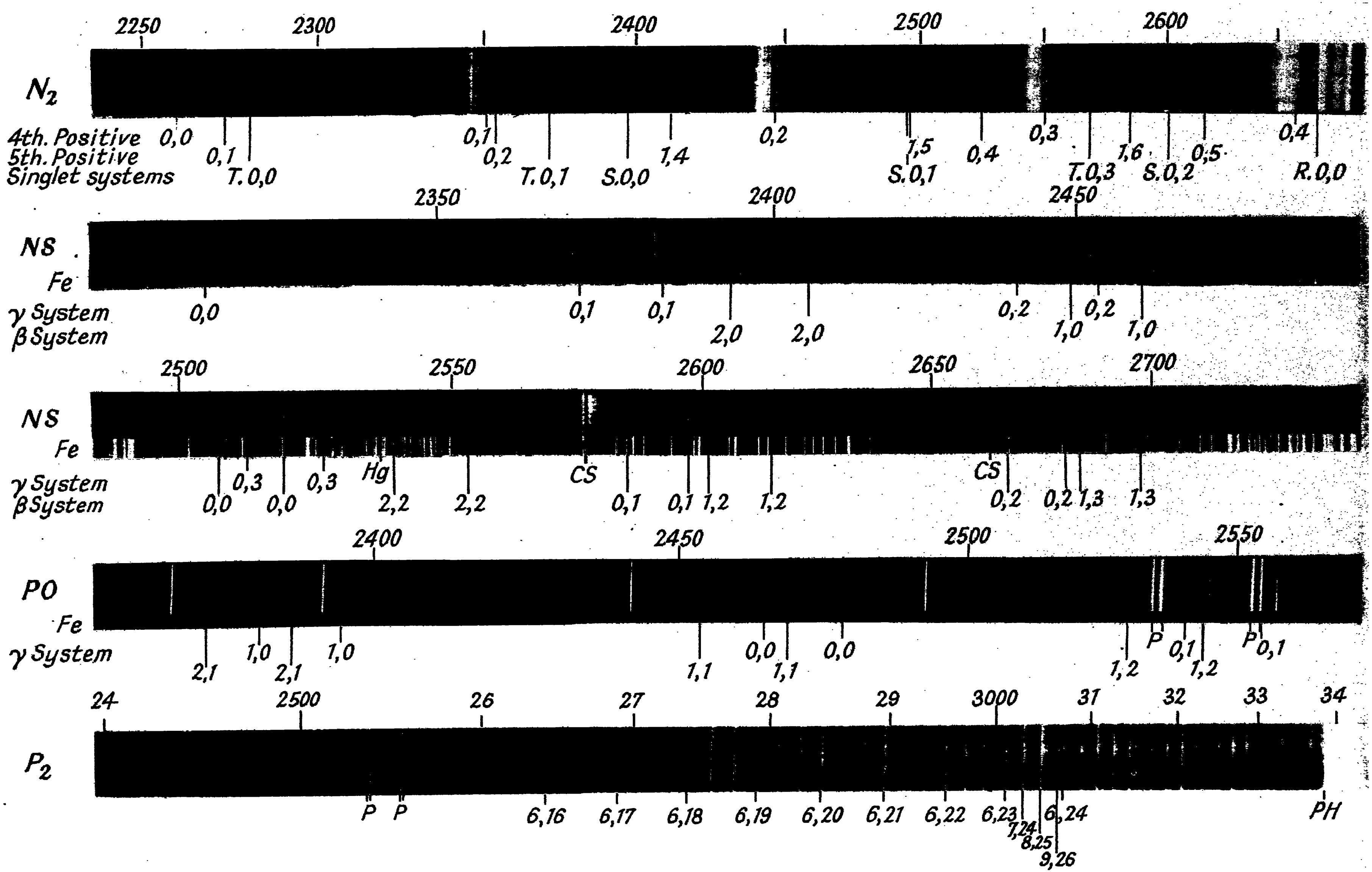
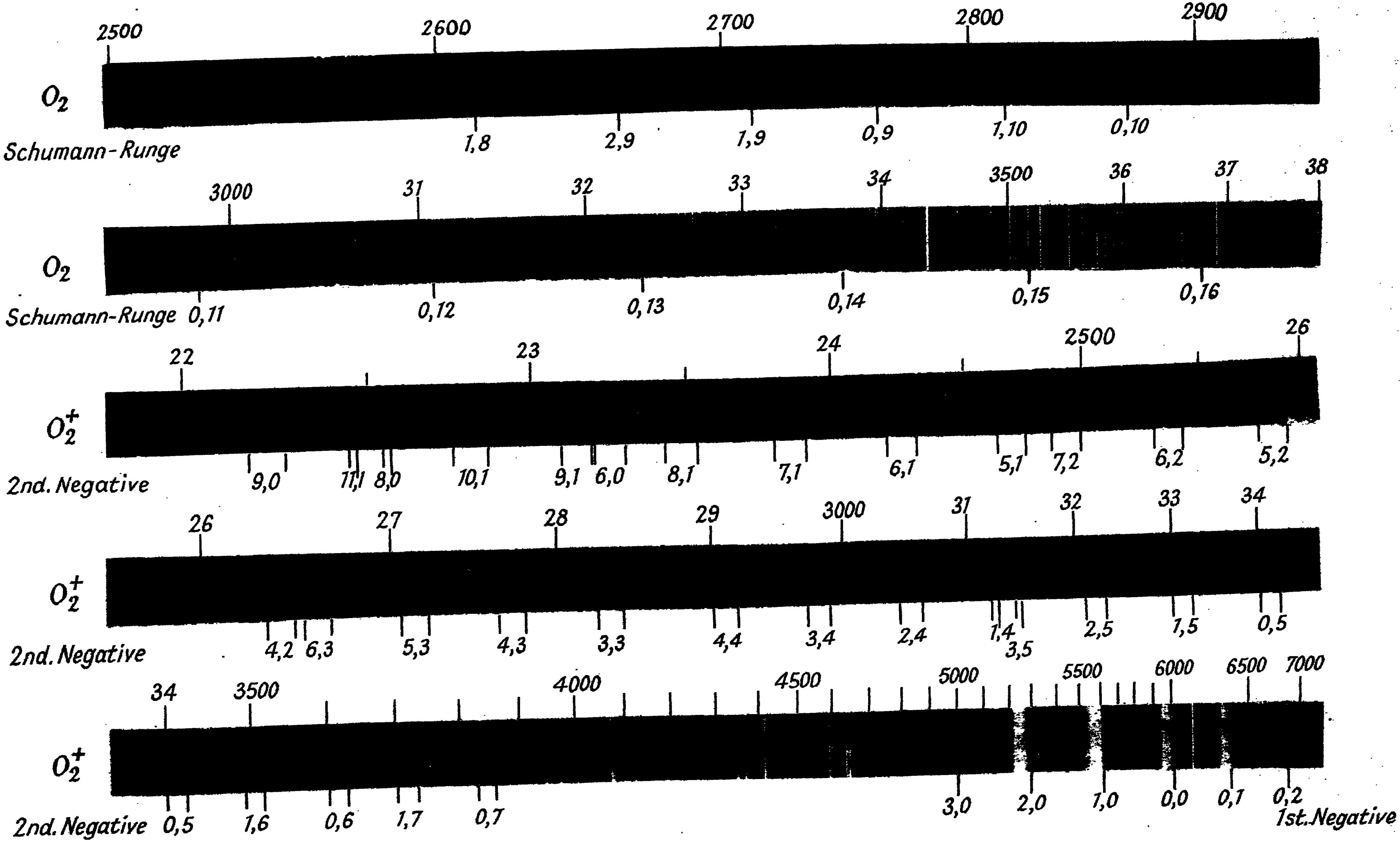
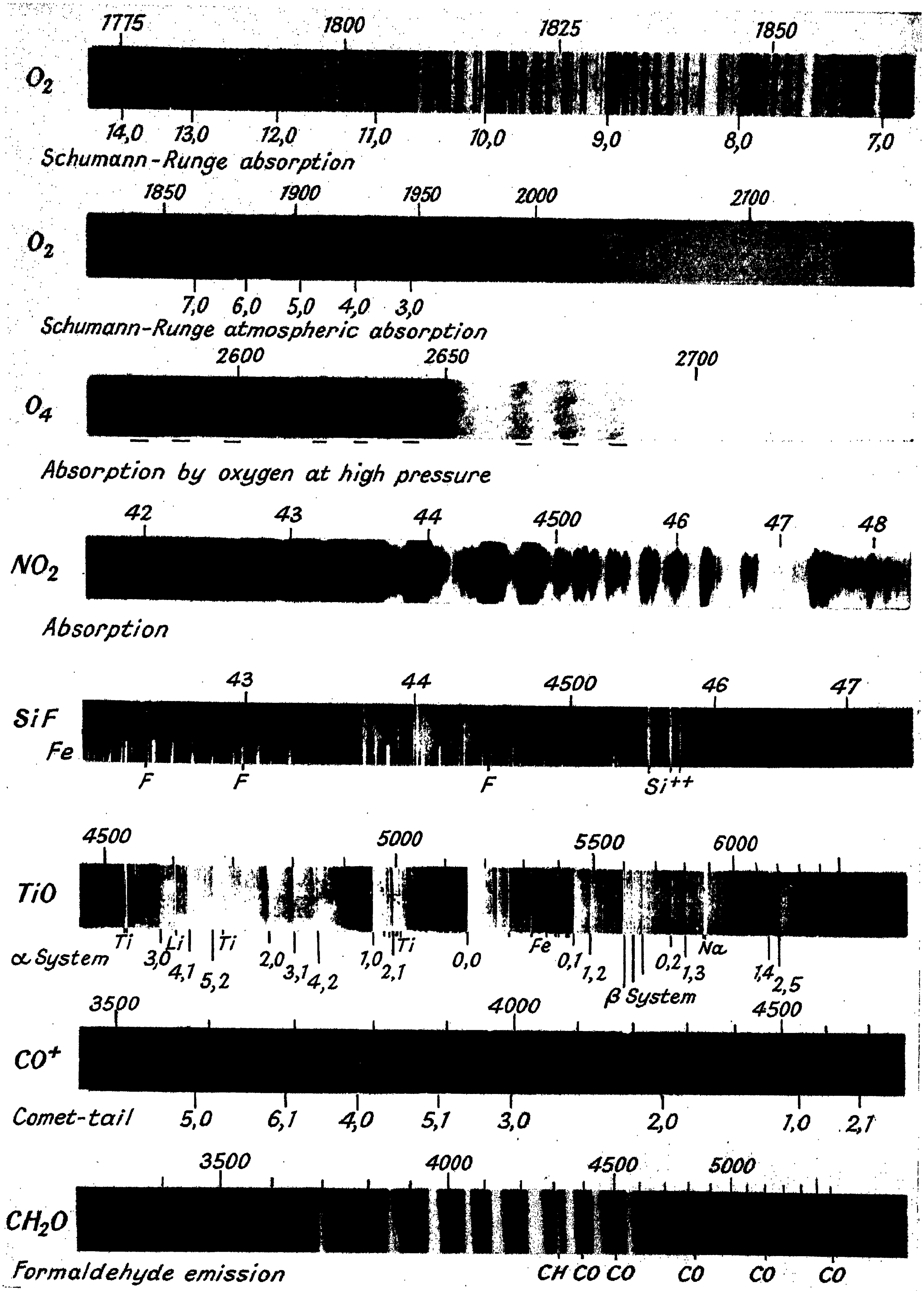

N2
4th. Positive
5th. Positive
Singlet systems
NS
Fe
γ System
β System
NS
Fe
γ System
β System
PO
Fe
γ System
P2
Hg
CS
PH

PLATE 7

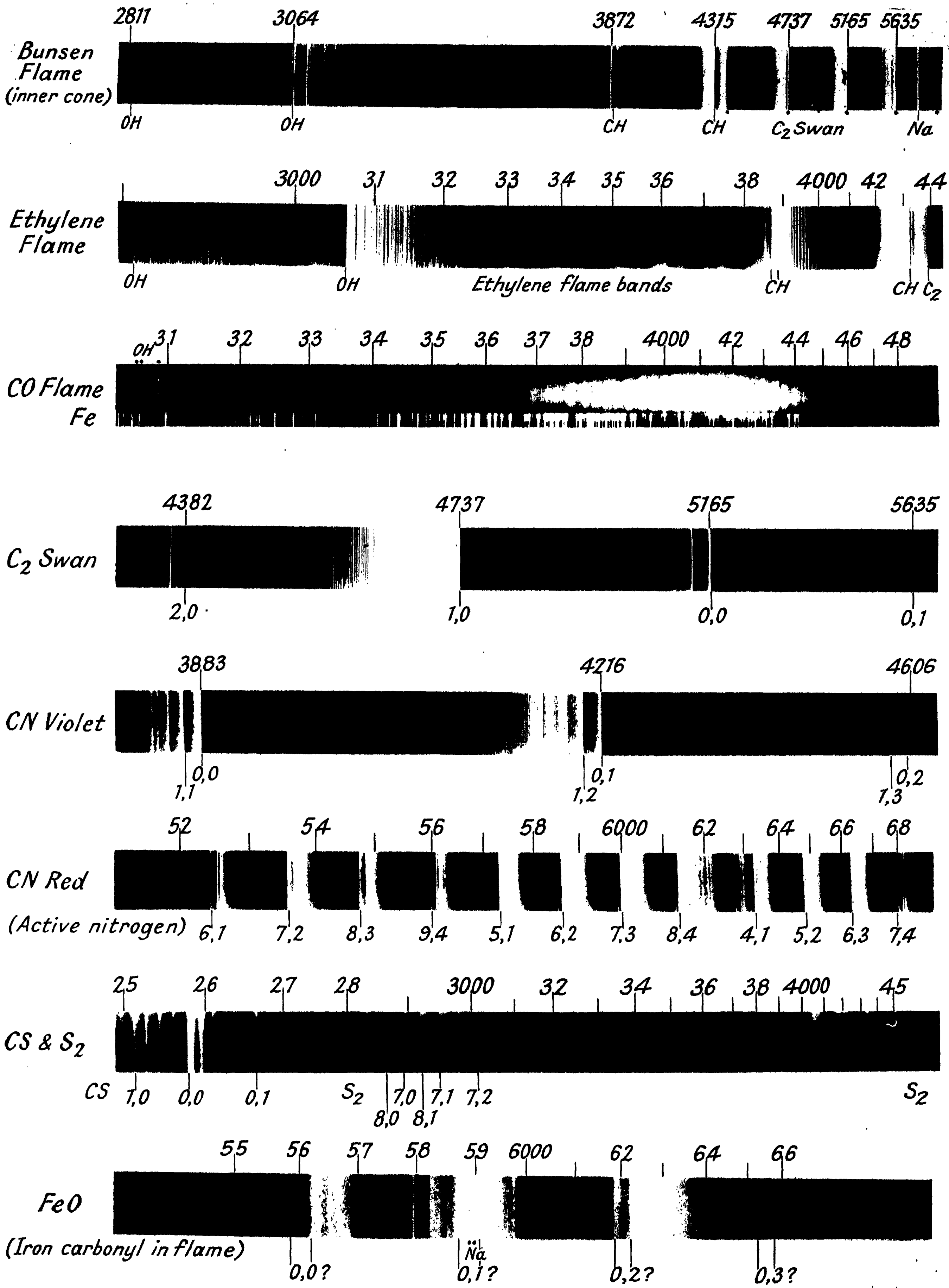


2500
2600
2700
2800
2900
O2
1,8
2,9
1,9
0,9
1,10
0,10
Schumann-Runge
3000
31
32
33
34
3500
36
37
38
O2
0,11
0,12
0,13
0,14
0,15
0,16
Schumann-Runge
22
23
24
2500
26
O2+
9,0
11,1
8,0
10,1
9,1
6,0
8,1
7,1
6,1
5,1
7,2
6,2
5,2
2nd. Negative
26
27
28
29
3000
31
32
33
34
O2+
4,2
6,3
5,3
4,3
3,3
4,4
3,4
2,4
1,4
3,5
2,5
1,5
0,5
2nd. Negative
34
3500
4000
4500
5000
5500
6000
6500
7000
O2+
0,5
1,6
0,6
1,7
0,7
3,0
2,0
1,0
0,0
0,1
0,2
2nd. Negative
1st. Negative

PLATE 8



1775 1800 1825 1850
O_2
14,0 13,0 12,0 11,0 10,0 9,0 8,0 7,0
Schumann-Runge absorption
1850 1900 1950 2000 2100
O_2
7,0 6,0 5,0 4,0 3,0
Schumann-Runge atmospheric absorption
2600 2650 2700
O_4
Absorption by oxygen at high pressure
42 43 44 4500 46 47 48
NO_2
Absorption
43 44 4500 46 47
SiF
Fe
F F F Si^{++}
4500 5000 5500 6000
TiO
Ti Li Ti Ti Fe Na
α System
3,0 4,1 5,2 2,0 3,1 4,2 1,0 2,1 0,0 0,1 1,2 0,2 1,3 1,4 2,5
β System
3500 4000 4500
CO^+
Comet-tail
5,0 6,1 4,0 5,1 3,0 2,0 1,0 2,1
3500 4000 4500 5000
CH_2O
Formaldehyde emission
CH CO CO CO CO CO


Bunsen Flame (inner cone)
2811 3064 3872 4315 4737 5165 5635
OH OH CH CH C2 Swan Na
Ethylene Flame
3000 31 32 33 34 35 36 38 4000 42 44
OH OH Ethylene flame bands CH CH C2
CO Flame
Fe
OH 31 32 33 34 35 36 37 38 4000 42 44 46 48
C2 Swan
4382 4737 5165 5635
2,0 1,0 0,0 0,1
CN Violet
3883 4216 4606
0,0 1,1 0,1 1,2 0,2 1,3
CN Red
(Active nitrogen)
52 54 56 58 6000 62 64 66 68
6,1 7,2 8,3 9,4 5,1 6,2 7,3 8,4 4,1 5,2 6,3 7,4
CS & S2
25 26 27 28 3000 32 34 36 38 4000 45
CS 1,0 0,0 0,1 S2 8,0 7,0 8,1 7,1 7,2 S2
FeO
(Iron carbonyl in flame)
55 56 57 58 59 6000 62 64 66
0,0? Na 0,1? 0,2? 0,3?

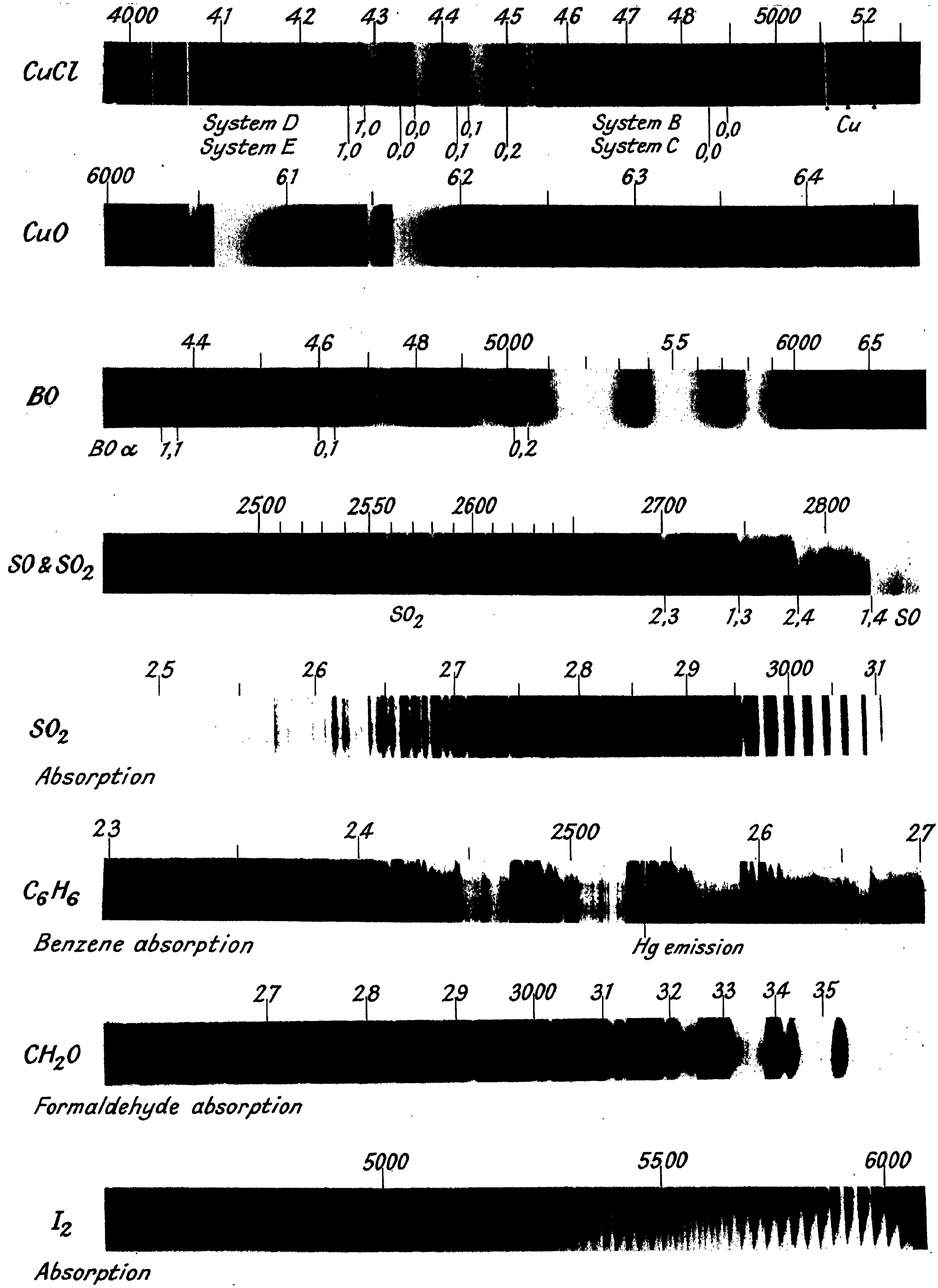

4000 41 42 43 44 45 46 47 48 5000 52
CuCl
System D 1,0 0,0 0,1
System E 1,0 0,0 0,1 0,2
System B 0,0
System C 0,0
Cu
6000 61 62 63 64
CuO
44 46 48 5000 55 6000 65
BO
BO α 1,1 0,1 0,2
2500 2550 2600 2700 2800
SO & SO_2
SO_2
2,3 1,3 2,4 1,4 SO
2,5 2,6 2,7 2,8 2,9 3000 31
SO_2
Absorption
23 24 2500 26 27
C_6H_6
Benzene absorption
Hg emission
27 28 29 3000 31 32 33 34 35
CH_2O
Formaldehyde absorption
5000 5500 6000
I_2
Absorption

PLATE II

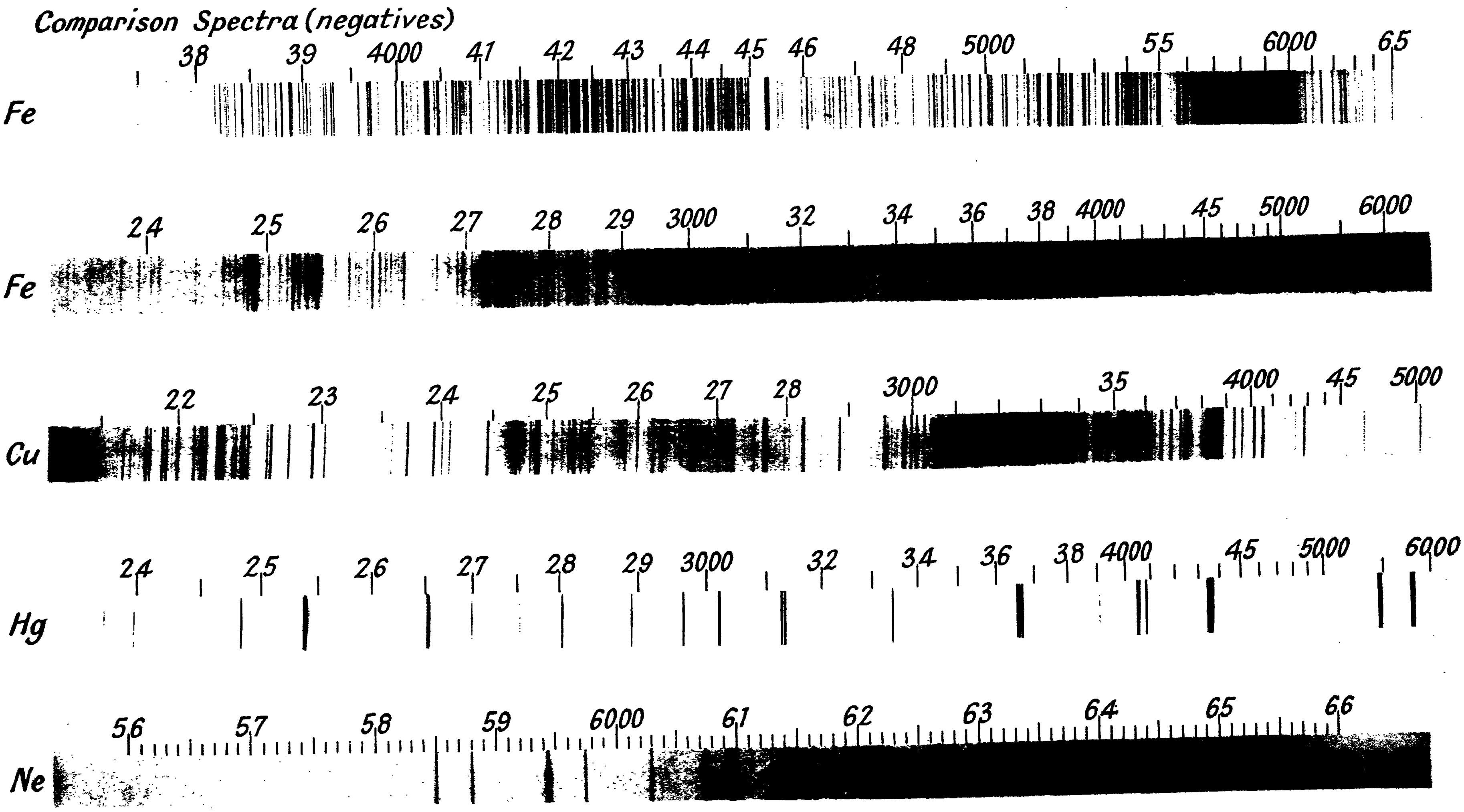
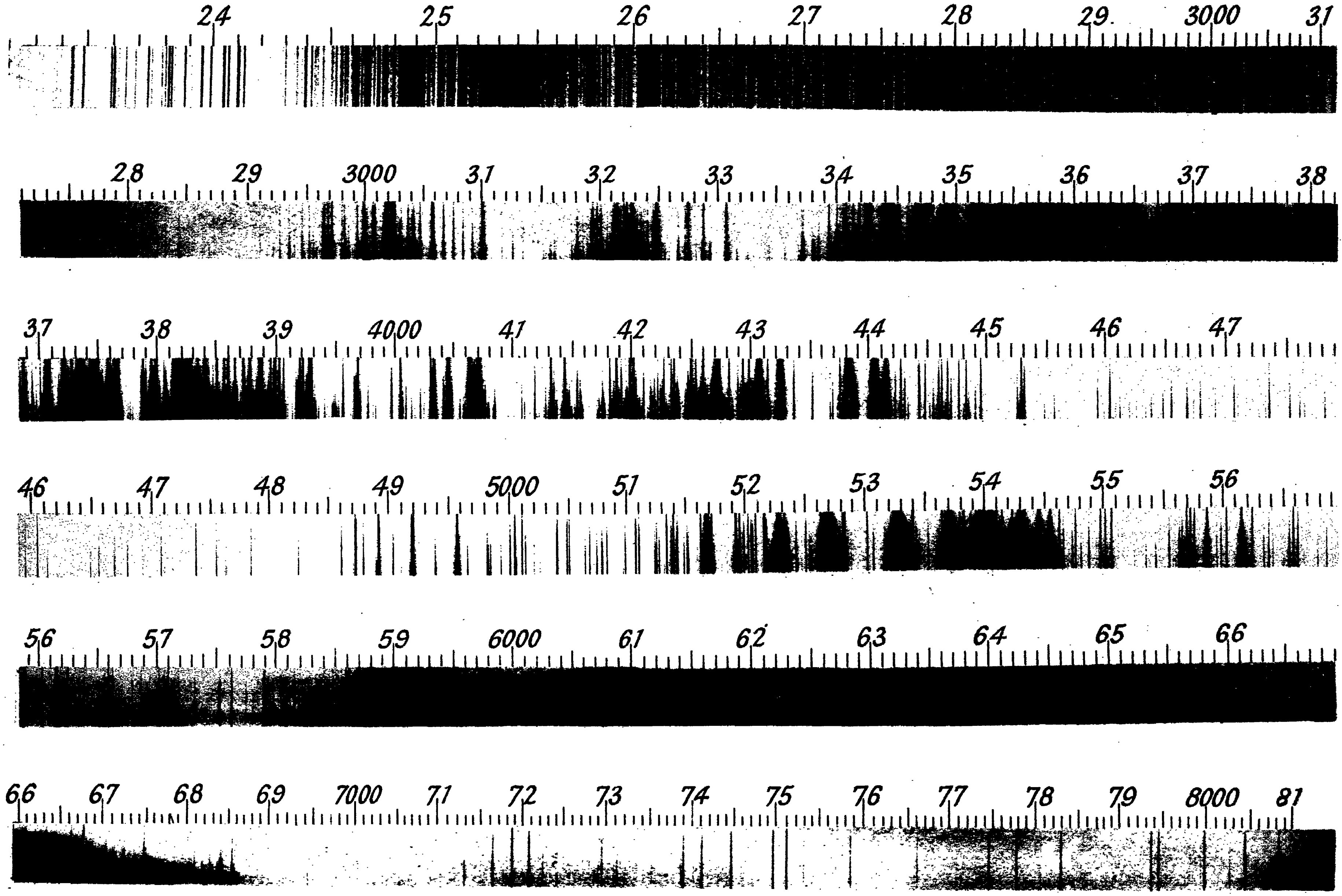

Comparison Spectra (negatives)
Fe
38 39 4000 41 42 43 44 45 46 48 5000 55 6000 65
Fe
24 25 26 27 28 29 3000 32 34 36 38 4000 45 5000 6000
Cu
22 23 24 25 26 27 28 3000 35 4000 45 5000
Hg
24 25 26 27 28 29 3000 32 34 36 38 4000 45 5000 6000
Ne
56 57 58 59 6000 61 62 63 64 65 66

PLATE 12

Iron Arc Spectrum (negatives)



APPENDIX

Persistent Atomic Lines

In the following table the most persistent atomic lines are given for each element. In addition to the "raies ultimes" usually quoted, we have given in many cases additional lines to cover regions in which there are no "raies ultimes."

For elements possessing a simple readily excited spectrum, *e.g.*, metals like Na, Ca, Al, intensities are quoted on a scale of 10 for the strongest line. For elements whose spectra are less distinctive and less easily excited, *e.g.*, Fe, W, the intensities are given on a scale of 8. For elements whose spectra appear with difficulty, *e.g.*, the non-metals, O, Cl, the intensities are given on a scale of only 5 for the strongest line. Lines which are readily observed in absorption are indicated by the letter *a* following the intensity. The intensities given are in most cases those for arc sources, or other mild conditions of excitation; for gases they refer to Geissler tube excitation.

A

8115·31	5
7503·87	4
7067·22	3
6965·43	4
4348·0	5

Ag

5465·48	7
5209·06	8
3382·89	10*a*
3280·67	10*a*

Al

3961·54	10*a*
3944·02	9*a*
3092·72	8*a*
3082·16	8*a*

As

2860·46	6
2780·20	6
2349·84	8
2288·14	6

Au

4792·62	6
2675·95	8*a*
2427·96	8*a*

B

2497·73	5
2496·78	4

Ba

5777·7	9
5535·53	10*a*
5519·11	6
3421·0	8

Ba$^+$

4934·09	8
4554·04	10

Be

4573·69	5
3321·35	6
3321·09	6
2650·78	5
2348·62	10*a*

Be$^+$

3131·06	8
3130·42	6

Bi

4722·55	8
3067·73	10
2989·04	7
2938·30	8
2897·98	9

Br

4816·72	4
4785·48	5
4704·83	5

C

2478·57	5

C$^+$

4267·27	5

Ca

5602·84	5
to	
5581·96	
5270·27	4
to	
5261·70	
4454·78	8
4434·96	7
4425·44	6
4318·65	6
to	
4283·10	
4226·73	10*a*

Ca$^+$

3968·47	10
3933·67	10

Cb (Nb)

4079·73	5
4058·94	8

Cd

6438·47	10
5085·82	6
4799·91	6
3610·51	9
3466·20	9
3403·65	8
3261·05	10
2288·03	9*a*

Ce

4628·15	
to	
4460·21	
4186·60	8
4165·61	4
4040·76	7
4012·40	6

Cl

4819·46	4
4810·06	5
4794·54	5

Co

3465·80	6
3453·51	8
3405·12	6
2407·26	4

Cr	
5208·43	6
5206·04	6
5204·54	6
4289·72	9*a*
4274·80	9*a*
4254·34	10*a*
3605·35	9
3593·48	9
3578·69	10

Cs	
8943·50	10*a*
8521·15	10*a*
4593·18	7*a*
4555·36	8*a*

Cu	
5220·06	4
5218·20	5
5153·26	4
5105·55	4
3273·96	9*a*
3247·55	10*a*

Dy	
4211·72	4
4167·97	1
4077·98	3
4046·00	3
4000·50	8

Er	
3906·34	5
3692·65	4
3499·12	3

Eu	
4205·03	5
4129·73	3

F	
6902·46	4
6856·01	5

Fe	
4957·61	5
4920·52	5
4891·50	4
3734·87	7*a*
3719·94	7*a*
3581·20	7
3570·10	7
3475·46	7*a*
3465·86	7*a*
3020·65	7*a*
2522·86	7*a*
2488·15	7*a*
2483·28	8*a*

Ga	
4172·05	10*a*
4033·01	10*a*

Gd	
3768·40	2
3646·19	10

Ge	
4226·61	7
3269·49	7
3039·08	8
2754·59	8
2709·61	8
2651·18	8

H	
6562·79	8
4861·33	6
4340·47	4

He	
5875·62	5
4685·75	2
3888·65	5

Hf	
4093·17	2
3134·72	8
3072·88	8
2940·77	6
2916·48	5
2904·41	3
2898·25	5

Hg	
5790·66	5
5769·60	5
5460·73	6
4358·34	6
4046·56	6
3650·15	6
2536·52	9*a*
1849·6	10*a*

Ho	
3891·02	5
3748·19	1

I	
5464·61	3
5161·19	5
3288·3	—
2062·38	—

In	
4511·31	10*a*
4101·76	8
3256·08	8
3039·36	7

Ir	
3513·67	5
3220·79	5
3133·34	5

K	
7698·98	9*a*
7664·91	10*a*
4047·22	4*a*
4044·16	5*a*

Kr	
5870·92	5
5570·29	5

La	
6249·93	4
5930·65	3
4429·90	5
4333·80	5
4123·23	6
4086·71	6
3949·10	8
3337·49	7

Li	
6707·86	10*a*
6103·64	5
4602·99	4
3232·61	3*a*

Lu	
4518·54	5
2911·39	2
2894·84	1

Mg	
5183·62	8
5172·68	7
5167·33	6
3838·26	7
3832·31	6
3096·92	8
2852·13	10*a*

Mg^+	
2802·71	8
2795·54	8

Mn	
6021·79	3
6016·64	3
6013·50	3
4034·49	10*a*
4033·07	10*a*
4030·76	10*a*
2798·27	6

Mo	
3902·96	7*a*
3864·12	8*a*
3798·26	8*a*
3193·98	6*a*
3170·34	6*a*
3132·60	6*a*

N	
4935·03	—
4447·0	—
4109·94	5
4099·94	2

N^+	
5679·5	5
5666·6	5

Na
5895·93 9*a*
5889·96 10*a*
3302·94 4*a*
3302·34 4*a*

Nd
4303·61 5
4177·34 1
3951·15 2

Ne
6402·25 8
5852·49 8
5400·56 8

Ni
3524·54 7*a*
3515·06 4*a*
3446·26 6*a*
3414·77 8*a*

O
7771·95 5
6158·21 3
5330·65 2
4368·30 2
3947·29 2

Os
4420·46 3
4260·85 3
3267·94 6
3058·66 6
2909·08 8
2488·55 6

P
2554·93 5
2553·28 8
2535·65 8
2534·01 6

Pb
4057·83 10
3683·47 8
3639·58 6
2833·07 5*a*
2170·00 —

Pd
3634·68 2
3609·55 2
3516·95 4
3421·23 6
3404·59 8

Pr
4225·34 1
4189·52 2
4179·43 5
4062·83 3

Pt
3064·71 8
2659·44 8

Ra
4825·94

Rb
7947·63 10*a*
7800·23 10*a*
6298·6 5
4215·58 8*a*
4201·81 8*a*

Rh
4374·82 4
3692·35 4
3434·90 8

Ru
3728·02 4
3726·93 4
3498·95 8
3436·74 4

S
4696·25 3
4695·45 4
4694·13 5

Sb
3267·48 4
3232·52 2
2877·92 8
2598·08 8
2528·53 8
2311·50 6*a*
2175·89 8*a*
2068·38 8*a*

Sc
4023·72 8
4020·42 5
3911·81 8
3907·48 5

Se
4742·25 3
4739·03 4
4730·78 5
2062·79 4*a*
2039·85 5*a*

Si
3905·52 1
2881·59 8
2528·52 4
2524·12 4
2516·12 5
2506·90 4

Sm
4424·35 5
4390·87 2

Sn
5731·70 1
3262·33 9
3175·05 10*a*
3034·12 8*a*
2863·32 10*a*
2839·99 10*a*
2706·50 8*a*

Sr
4962·26 3
4872·49 2
4832·08 5
4607·33 10*a*

Sr^+
4215·52 6
4077·71 10

Ta
6485·36 1
3318·85 5
3311·14 5
2714·68 8

Tb
3874·19 5
3848·76 2
3561·75 5
3509·18 5

Te
2769·65 4
2385·78 5
2383·27 5
2142·75 4*a*

Th
4019·14
3601·05
3538·75

Ti
4999·51 2
4981·73 3
4536·05 4
to
4533·25
3998·64 6
3371·46 6
3341·87 8

Ti^+
3372·80 6
3361·22 6
3349·41 6
3349·04 5

Tl
5350·47 10
3775·73 9*a*
3519·24 7
2918·32 2
2767·87 2*a*

Tu
3761·91 4
3761·34 5
3462·21 4

U
5527·84
4241·68
3672·58

V
4460·31 5
4408·52 5
to
4379·24 8
4128·07 8
3185·41 8
3183·99 8

W
4302·11 6
4294·62 5
4008·76 8
3617·52 3

Xe
4671·22 5
4624·27 2
4500·98 1

Y
4674·85 4
4643·69 2
4374·95 4
4142·87 6
4102·38 8
3774·33 6
3710·30 6
3242·28 6

Yb
3988·01 5
3694·20 3
3289·73 3

Zn
6362·35 6
4810·53 10
4722·16 10
4680·14 9
3344·91 9
2138·61 5*a*

Zr
4710·07 1
4687·80 2
3601·19 5
3547·68 3
3519·61 2
3481·15 1

Zr$^+$
3572·47 1
3496·21 2
3438·23 3
3391·98 5

For the most complete and recent work on line spectra, the reader is referred to "Massachusetts Institute of Technology Wave-length Tables," edited by G. R. Harrison (John Wiley and Sons, New York: Chapman and Hall, London; (1939)).

Conversion of Wave-lengths on Rowland's Scale to International Angstroms

Range in A.	Correction (subtract)	Range in A.	Correction (subtract)
2950–3125	0·12	5400–5500	0·21
3125–3250	0·13	5500–6050	0·22
3250–3450	0·14	6050–6500	0·21
3450–4150	0·15	6500–6570	0·22
4150–4350	0·16	6570–6750	0·23
4350–4550	0·17	6750–6850	0·24
4550–5125	0·18	6850–7000	0·25
5125–5300	0·17	7000–7200	0·26
5300–5325	0·18	7200–7400	0·27
5325–5375	0·19	7400–7700	0·28
5375–5400	0·20		

Conversion of Wave-lengths in Air to Wave-lengths in Vacuo

λ_{air}	add	λ_{air}	add	λ_{air}	add	λ_{air}	add
15,000	4·10	7800	2·14	5800	1·60	3800	1·07
14,000	3·83	7600	2·09	5600	1·55	3600	1·02
13,000	3·55	7400	2·04	5400	1·50	3400	0·97
12,000	3·28	7200	1·98	5200	1·44	3200	0·92
11,000	3·01	7000	1·93	5000	1·39	3000	0·87
10,000	2·74	6800	1·87	4800	1·34	2800	0·82
9500	2·60	6600	1·82	4600	1·28	2600	0·78
9000	2·46	6400	1·77	4400	1·23	2400	0·73
8500	2·33	6200	1·71	4200	1·18	2200	0·69
8000	2·20	6000	1·66	4000	1·13	2000	0·65

Physical Constants, etc.

c velocity of light, $2{\cdot}9977 \times 10^{10}$ cm./sec.
e electronic charge, $4{\cdot}802 \times 10^{-10}$ E.S.U.
h Planck's constant, $6{\cdot}624 \times 10^{-27}$ erg. sec.
k Boltzmann factor, $1{\cdot}381 \times 10^{-16}$ erg./deg.
N Avogadro's number, $6{\cdot}023 \times 10^{23}$ molecules/mole.
n Loschmidt's number, $2{\cdot}687 \times 10^{19}$ molecules/c.c. at S.T.P.
m mass of electron, $9{\cdot}107 \times 10^{-28}$ gm.
m_H mass of hydrogen atom, $1{\cdot}673 \times 10^{-24}$ gm.
R_H Rydberg constant for hydrogen, $109677{\cdot}7$ cm.$^{-1}$
$R\infty$ Rydberg constant, infinite mass, $109737{\cdot}1$ cm.$^{-1}$

1 A. (angstrom)	$= 10^{-8}$ cm.
1 μ (micron)	$= 10^{-4}$ cm.
1 gm. calorie	$= 4{\cdot}185 \times 10^{7}$ ergs.
1 electron-volt	$= 1{\cdot}602 \times 10^{-12}$ ergs.
1 electron-volt	$= 8067{\cdot}5$ cm.$^{-1}$ (wave-numbers) $= 23{,}053$ gm. cal./mole.
1 cm.$^{-1}$	$= 2{\cdot}86$ gm. cal./mole.

AUTHOR INDEX

SUBJECT INDEX

Chemical symbols of molecules are given in the tables of "Individual Band Systems" in alphabetical order and are therefore not included in this index; the chemical symbols given here are ones which are sometimes used as alternatives to those listed in the book.